同濟大學
TONGJI UNIVERSITY

A dissertation submitted to

Tongji University in conformity with the requirements for

the degree of Master of Engineering

# Distribution of refrigerated products to Family Mart stores in Shanghai

Candidate: **Marta Domènech Roca**

Student Number: **1893012**

School/Department: **Transportation Engineering**

Discipline: **Master of Engineering**

Major: **Transportation Engineering**

Supervisor: **Chang Lin**

June 2018

Distribution of refrigerated products to Family Mart stores in Shanghai Marta Domènech 同济大学

# 学位论文版权使用授权书

# 同济大学学位论文原创性声明

本人郑重声明：所呈交的学位论文，是本人在导师指导下，进行研究工作所取得的成果。除文中已经注明引用的内容外，本学位论文的研究成果不包含任何他人创作的、已公开发表或者没有公开发表的作品的内容。对本论文所涉及的研究工作做出贡献的其他个人和集体，均已在文中以明确方式标明。本学位论文原创性声明的法律责任由本人承担。

学位论文作者签名：

年　月　日

# Acknowledgements

First and foremost, I would like to express my sincere gratitude to my thesis supervisor Professor Chang Lin. Thank you very much for your support, understanding and assistance during the thesis.

I would also like to thank Jaume for his brilliant mind and his support. Thank you for assisting me when I needed it, with patience and comprehension.

There is no doubt that getting through the thesis required more than academic support. I have no other choice than being grateful with everybody that has shared this great journey with me. Particularly, I would like to thank Alejandro, Nil and Ander. People may say that being so far from home is not always easy. Well, they not only made it easy but an amazing experience. Thank you for your care and love.

Here once more, I would also like to thank Roxane for her unconditional support at home. Our late-night conversations have let us learn from each other, acquire new perspectives of life but, what is even more important, have fun. Thank you for being a constant light of joy.

Finally, this thesis personally represents the end of an intense period that started seven years ago. Hence, most importantly, I need to thank my family. Not only they have supported me in every decision I have taken, but also have given me the strength and courage to make it happen, to move always a step forward. Thank you for making me always believe that there are no limits, for believing in me more than I do. *Gràcies*.

# Abstract

Provisioning and replenishment of goods is essential for the success of Family Mart stores. Family Mart is a convenience store franchise chain launched in Japan that has expanded to more 7 countries, China among them. The stores mainly offer goods such basic grocery, take away food, drinks, bento, magazines and drugstore products. However, its great success it is not only based on the fact that it meets the basic needs of customers but their presence all over Shanghai and the opening hours.

The current distribution of Family Mart stores is performed by Hitachi Transport Systems S.L, who is responsible of distributing all the products to more than 450 Family Mart stores in Shanghai. Hitachi uses a Transport Management System (TMS) to determine the best routing based on the demand. However, it is interesting to understand what is in the black box of the TMS.

Consequently, the problem raised in this dissertation is to find a mathematical formulation to model the distribution of refrigerated products from the warehouse to the more than 450 Family Mart stores. Therefore, the problem is not just proposing a mathematical formulation but also implementing it, so a good routing distribution can be given.

For that, two different resolution methods are outlined based on the formulation of the Vehicle Routing Problem. On one hand, two different formulations are created in order to obtain the optimal solution. On the other hand, since finding the optimal solution might have a high computational cost, a heuristic formulation is also defined to obtain a near-optimal solution.

Both methods are implemented so a solution for the problem raised can be found. Moreover, given the efficiency of the heuristic, the effect of some parameters can be assessed. The parameters studied are the demand, the instant when the demand needs to be supplied and, also, the instant when the demand needs to be supplied.

The results show that the parameter with greater effects is the time restriction. Moreover, the instant when the demand needs to be supplied has a greater effect than the demand itself. Furthermore, although both resolutions cannot be compared due to the fact that their aim differ a bit, it can be stated that the heuristic performs quite good.

**Key Words:** Vehicle Routing Problem, optimal solution, heuristic, implementation, time window, demand, instant demand

# Table of contents

# Chapter 1: Introduction

## 1.1 Project Overview

Just a 15 minutes walk around Shanghai is needed in order to realize that Family Mart is a constant actor in the scenery.

Family Mart is a convenience store franchise chain launched in Japan that has expanded to more 7 countries, China among them. Family Mart stores mainly offer goods such basic grocery, take away food, drinks, bento, magazines and drugstore products. However, its great success it is not only based on the fact that it meets the basic needs of customers but their presence all over Shanghai and the opening hours. There is always an opened Family Mart store nearby to buy that product we forgot to buy.

Given the kind of products and the size of the stores, provisioning and replenishment of goods is essential for a proper operation and performance of every store. For that, every store is daily visited at least twice, once for refrigerated products and another one for frozen products.

The current distribution of Family Mart stores is performed by Hitachi Transport Systems S.L, who is responsible of distributing all the products to more than 450 Family Mart stores in Shanghai. Hitachi uses a Transport Management System (TMS) that, based on the demand of every store, determines the best routing. However, it is interesting to understand and be able to recreate what is in the black box of the TMS.

Based on this idea, the problem raised in this dissertation is to find a mathematical formulation to model the distribution of refrigerated products from the warehouse to the more than 450 Family Mart stores. Hence, the problem is not just proposing a mathematical formulation but also implementing it, so a good routing distribution can be given.

Since the problem is to find the optimal or near optimal routes to deliver a given demand to a set of customers with the minimum cost, the problem can be understood as a

Vehicle Routing Problem with some constraints, more precisely, as a Capacitated Vehicle Routing Problem with Time Windows.

In order to solve the problem, two resolution methods are described. On one hand, two mathematical formulations are outlined in order to obtain the optimal solution. Moreover, on the other hand, since finding the optimal solution might have a high computational cost, a heuristic formulation is also defined in order to obtain a near-optimal solution.

Both resolution methods are implemented in different solvers in order to obtain a numerical solution for the problem raised. Moreover, different values for the demand, the instant of the demand and time window parameters are implemented in order to analyse their effect in the resulting routing.

Finally, the results are presented and analyzed, so some conclusions regarding the effect of the three parameters can be drawn, besides giving a good routing for distributing the demand.

## 1.2 Thesis Overview

In order to achieve the proposed objectives several tasks have been developed, which give content to the various chapters of this thesis. Below the methodology followed in each one is briefly described.

In Chapter 2, as a result of a deep literature review, the overall picture of the most significant features of vehicle routing problems and more precisely the Vehicle Routing Problem are presented. The study highlights its history and applications as well as its complexity, variants and variants. The chapter finishes with the formulation of the problem and a brief explanation of different resolution methods.

After the state of the art in Chapter 2, the firm Family Mart is presented in Chapter 3. Hence, a brief description about the company and its organization is outlined. Furthermore, it is also described its current operation for distributing products around Shanghai and the organization of its warehouse.

Chapter 4 introduces the problem to be solved, its characteristics and objectives. Through the chapter it is explained the hypothesis and assumptions taken as well as the data provided. Finally, the chapter finishes with an explanation of the data treatment undertaken.

Subsequently, in chapter 5, two formulations to outline the problem are derived based on the resolution methods explained in Chapter 2: two-index and three-index formulations. Moreover, the objective functions and restrictions used in every formulation are precisely described. The chapter finishes with a brief comparison of the two formulations performed.

Chapter 6 presents another resolution method, a heuristic based on Clark and Wright heuristics. Through the chapter it is explained its concept, the data needed in order to be implemented and its mathematical formulation.

After the resolution methods explained in Chapter 5 and Chapter 6, in Chapter 7 it is precisely described the implementation of both methods. For that, the use of solvers CPLEX and Matlab is needed. The chapter also presents the instances solved with every method.

Chapter 8 presents the results of the implementation outlined in Chapter 7. First, the results by means of CPLEX are described so a near-optimal solution is obtained. Furthermore, the chapter presents the results obtained by implementing the heuristics. Finally, the chapter finishes with a brief comparison of both resolution methods.

The last chapter of this thesis, Chapter 9, presents in the first place the conclusions emerged from the distinct tasks performed. Subsequently, various lines of future research arising as a result of the work undertaken.

# Chapter 2: Theoretical background. Vehicle Routing Problem

## 2.1 Introduction

In this chapter, the focus relies on routing problems, more specifically on the Vehicle Routing Problem. First of all, the definition and types of routing problems are described. Thereafter, the Vehicle Routing problem is approached, starting from its history, applications, complexity and variants. Furthermore, the mathematical formulation is given. Finally, the chapter finishes with a review of the solution methods, including both the exact and heuristic methods.

## 2.2 Routing problems

Routing problems are one of the key aspects of transport and logistics field because of their great impact. A route problem is known to be a type of optimization problem arising when there is a set of customers requesting a service whose demand has to be satisfied so that the best routing needs to be found.[40] The importance of these problems is given by the large number of real life applications. Some of the typical examples are the school bus, mail distribution or garbage collection but there is an endless list of other applications. Given the great potential of these kind of techniques, logistic companies are increasing their investment in research and software capabilities to solve more complex problems.

Before getting closer to the vehicle routing problems, it is worth stressing the main difference between vehicle routing problems and path problems. While in vehicle routing problems there is a set of nodes or arcs that must be visited, in path problems it must be found a route to connect an origin and destination, no matter what are the nodes or arcs visited on the way. This dissertation focuses on the first kind of problem, that is to say, vehicle routing problems.

There are many different kinds of routing problems depending on the set of additional constrains the problem must satisfy. The most common constraints are the number of vehicles, their capacity, time window or the kind of service demanded.

There are mainly two big type of vehicle routings problems depending on whether the demand is located in the nodes or in the arcs, as it can be seen in Table 2.1. On one hand, when the demand is located in the nodes, the optimal route must visit all the nodes. On the other hand, when demand is located in the arcs, the optimal route must visit all the arcs. In other words, node problems are used when clients are represented by nodes while in arc problems it is understood that the streets are the clients that must be visited.

| **Demand** | **Capacity Constraints** | **Problem** | **Other constraints** |
|---|---|---|---|
| Nodes | No | Travelling Salesman Problem (TSP) | |
| | Yes | Capacitated Vehicle Routing Problem (CVRP) | Pickup/Delivery<br>Time Windows |
| Arcs | No | Chinese Postman Problem (CPP)<br>(One connected component) | |
| | | Rural Postman Problem (RPP)<br>(Several connected components) | |
| | Yes | Capacitated Arc Routing Problem (CARP) | |

Table 2.1. Classification of routing problems.

The story of routing problems based on nodes begins in century XIX, when W.R. Hamilton coined the Icosian game. Icosian game is a board game that consist on finding a route to connect the 20 nodes of the board and come back to the origin node just using the allowed arcs, as seen in Figure 2.1. Some time later, a path that visits each vertex exactly once and comes back to the origin became known as Hamiltonian cycle. It is worth highlighting that two years before the game was introduced, T. Kirkman posed the problem in a paper submitted to the Royal Society wondering if there is a cycle that pass by every vertex of a polyhedron.[6]

There are mainly two routing problems based on nodes: Travelling Salesman Problem (TSP) and Vehicle Routing Problems (VRP). However, they are extremely related since the VRP can be understood as an extension of the TSP.

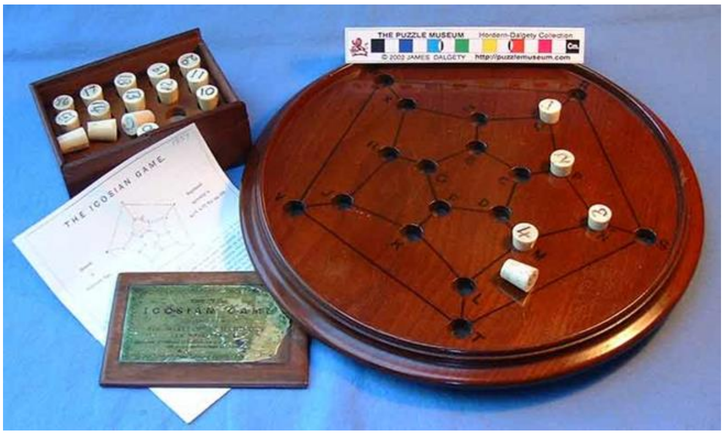

Figure 2.1. Hamilton's Icosian game

Traveling Salesman Problem (TSP) is one of the most famous and investigated problems of the field since, in spite of its apparent simplicity, it is really complex to solve. Travelling Salesman Problem owes its importance to the great range of applications, starting from logistics and distributions until genetic aspects. The problem aims to define the optimal route to visit all the nodes of a graph and come back to the origin given that all the distances between nodes are known.

The story of the Travelling Salesman Problem starts in 1832 with a book called *Travelling salesman: how he should be and what he has to do to get commissions and success in business. From a veteran travelling salesman* [34] Although the book focuses on other aspects of the profession, in the last chapter it is explicitly defined the travelling salesman problem. Based on it, the path chosen has a great impact when considering saving time so that the important fact is to visit as many locations as possible without visiting the same client more than once. However, it was not until the 1930s that a mathematical approach was studied. It is interesting to see that the problem was first outlined by a business man one century before this kind of problems began to be studied.

The other important type of routing problems based on nodes is the Vehicle Routing Problem (VRP). The problem seeks to find what is the optimal set of routes for a fleet of vehicles to supply the demand of a given set of customers. VRP is the main topic of this chapter. Consequently, more detailed information about its history, applications and formulation can be found in the following sections.

The second big kind of routing problems are the problems based on arcs. Its story begins in century XVIII in Königsberg, a small village located in the west side of Russia. Pregel river divided the village in four areas connected with 7 bridges. Königsberg's habitants started wondering if it may exist a walk through the city that would cross each of those bridges once and only once and that would come back to the origin again. L. Euler proved that the problem has no solution but, what is more important, he pointed a relevant fact: the choice of route inside each land mass was irrelevant, what really mattered was the sequence of bridges crossed. Therefore, he changed the mass land to nodes and the bridges to arcs as seen in Figure 2.2. Hence, the aim was to visit all the arcs in a route, what is also called a routing problem based on arcs.[12] The formulation of the problem and its solution can be found in [15].

Figure 2.2. Reformulation of the problem in abstract terms. Source: [12]

It is important to note that the aim of the seven bridges of Königsberg problem was not to find the optimal path but the existence of one, what is the essence of routing problems. In this respect, the first problem was raised in by M. Guan in 1960, in an article of a Chinese newspaper, later translated to English in 1962 [20].

The problem described by M. Guan is called the Chinese postman problem (CPP), postman tour or route inspection problem and its aim is to find a shortest closed path that visits every edge of a connected graph at least once. As it was proven by L. Euler, in order to exist a solution, the degree of the nodes needs to be even. Based on this approach, the solution proposed by Guan consists of adding arcs of minimum cost to the original graph so that it can become an Eulerian graph. Once an Eulerian graph is obtained, it is easy to determine a cycle that visits every arc just and only once. It is necessary to understand that an Eulerian graph, whose name comes from L. Euler, must have at least one Eulerian cycle, that is to say, a closed cycle that uses every arc just and only once. For that, all nodes must have even degree with the exception of existing an even number of odd degrees nodes, as proved by Hierholzer in 1873.[21]

Another of the well-known routing problems based on arcs is the Rural Postman Problem (RPP), which is probably the problem based on arcs that better fits reality. The Rural Postman Problem, first described in 1974[36] aims to find the shortest closed path that visits just some of the arcs of a graph, so there are some arcs that do not necessary need to be visited. Two years later it was proved that RPP is a NP-problem, concept explained Section 2.5 , unless the subgraph of the required arc is completely connected. Then, it becomes a CPP problem, for which exists algorithms that solve the problem in a polynomic time.[30]

Last but not least, the Capacitated Arc Routing Problem (CARP), first described by B. L. Golden and R.T. Wong in 1981,[18] arises in the case there is capacity constraints. In this case, the demand of every client is assigned to every arc of the graph and a vehicle fleet with a fixed capacity must visit all arcs delivering or picking up the corresponded demand of every arc, without exceeding vehicle’s capacity. However, it is important to note that the demand must be non-negative, consequently, it can be stablished as 0. A similar problem with strictly positive demand was investigated some years earlier in 1973 by N. Christofides.[3] It is interesting to note that in the case described by Golden and R.T. Wong, when the demand of some arcs can be 0, the problem becomes an RPP problem with capacity constraints while in the case described by N. Christofides where the demand cannot be 0, the problem becomes a CPP with capacity constraints.

From now on, all the sections of this chapter focuses on Vehicle Routing Problem, the problem described in this dissertation.

## 2.3 History

In the scientific literature, Dantzig and Ramser [5] were the first authors that talked about VRP problem when they were investigating its real implementation in distributing petrol to petrol stations. In their article *The truck Dispatching Problem (1959) [5]* they proposed a solution based on a linear problem formulation that would result as a near-optimal solution. The aim was to find a way to assign the trucks to petrol stations so that their demands were covered and the distance overcome for the fleet truck was minimum. For them, the problem was just a generalization of the TSP, when it is mandatory to visit the origin once *m* out of *n-1* petrol stations are visited. Hence, for known values of *m* and *n*, the aim is to find the loops so that they all have a node in common and the distance overcome would be minimum. This problem was later outlined as Cover Leaf Problem.

It is important to note that for small values of *m*, the problem could be easily solved by looking at a plan were all the nodes would be located and find clusters of nodes. However, when it is difficult to determine the clusters and *m* is a large value, the problem is more complex and other kind of solutions must be found.

## 2.4 Applications

During the first years of VRP development, the clear majority of the VRP where applied to solve scholar routes and logistics. Although logistics may seem the greatest and most common application field, there are plenty of other fields where the VRP can be applied. Just some of them are explained as follows, since the possibility of applying a VRP to solve a real-life problem might fill and endless list.

- **Logistics**

The most numerous application of the VRP regard to the logistics field. Public, freight and vehicle transport are some applications that perfectly fit VRP problems. Some of the most common applications are:

- Product distribution

The distribution of products from a warehouse is the typical and most common application of the VRP. For instance, it can be considered the collection of blood samples from different hospitals to the lab where the samples are analyzed. Another example would be the replenishment of products to any shop or supermarket.

- Scholar routes

Scholar routes are one of the main applications of TSP and VRP. Nowadays, companies engaged in public transportation or simply human transportation normally use a software to solve VRP so great savings can be achieved.

- Urban freight transport

Nowadays, overall urban logistic is changing since parcel delivering is getting more importance given the increase of e-commerce. Consequently, there are new ways of distributing urban freight. As an example, a mobile depot is a truck used as a small warehouse stablished, every day, in a different point of the city. From it, e-bikes are responsible to take the parcels and deliver them to the client. Consequently, this last-mile delivery would solve a VRP to outline the best routes from the mobile depot to all customers.

- Mail delivery

Although usually the mail is outlined as a problem based in arcs, when the locations are really far from each other, it is better to apply a VRP to get the best route.

- **Tourism.**

When thinking about visiting a city and its surroundings, one is normally based in a hotel or hostel and every day visits an area of the city. When organizing a trip, although a VRP is not normally applied, the reasoning for organizing it is trying to figure out what is the best way to visit all the interesting points without losing a lot of time from point to point. Consequently, it can be understood as solving a VRP considering also some other constraints such opening hours of touristic places.

- **Industry**

The range of applications in the industry is, as expected, not as wide as in the logistic field. However, the implementation of the problem in the area has also implied great cost savings. Some of the most common applications are:

- Sequencing of tasks

Assuming that a machine, capable of performing 3 task simultaneously, must perform a task series in any order with the lowest possible time. However, the machine takes some time $t_{ij}$ for tuning from changing to task $i$ to $j$. In this case, a VRP can be applied assuming that every task is a node to be visited and the depot is the machine status when no task is performed.

- Connecting chips

This kind of example can be often found in laptop designs or any other digital device. Inside all digital devices there are plates with chips that must be connected each other with cables. Given the small size of the chips and interference problems, more than two cables cannot be added in the same pin. Consequently, the minimum amount of cable necessary to connect all the points must be found, so a TSP or VRP must be solved.

- Drilling problems

When manufacturing the door of a car, for instance, it must be drilled several times in order to introduce all the control and electronic devices found inside. Usually, a programmed machine bores the steel sheet in an order predefined. If it is not well programmed, the time needed to change from site to site that must be drilled can significantly increase overall performance. Consequently, a possible application of a TSP or VSP would consist on outlining the sites where the door must be drilled as nodes to be visited and minimize the total distance from going from site to site. The origin and final point can be determined as machine initial position.

As previously said, these are not the only areas where VRP could be applied. It exists many other problems that can be solved by means of VRP. As a matter of fact, in the last years many applications in genetic raised.

## 2.5 Complexity

It is interesting to analyze the complexity of the VRP, that is to say, the computational resources needed to solve the problem. However, first it is necessary to introduce computational complexity theory and the different complexity classes defined by it.

As suggested, computational complexity theory is a field in theoretical computer science and mathematics that deals with the resources required in the computational process in order to obtain a solution for the desired problem. Actually, one of its main goals is to classify and compare the practical difficulty of solving problems in terms of computational resources. Most of the complexity theory deals with decision problems that can be answered by 'yes' or 'no' and depending on the difficulty, they are classified into a class or another.

When a problem can be solved by a deterministic algorithm in a polynomial time, it is said that the problem belongs to Class P. Hence, class NP (Non-deterministic Polynomial acceptable problems) is the set of decision problems which there is no known polynomial algorithm, so that the time to find a solution grows exponentially with problem size. Obviously, $P \subseteq NP$ but it is still a topic of research whether $P = NP$. In fact this is one of the seven millennial problems stated by the Clay Mathematics Institute in 2000 and a prize of 1M dollars is awarded by the institute to the discoverers.[11] Every year there are multiple proposals trying to prove that $P = NP$, mostly based on an algorithm for the Travelling Salesman Problem (TSP) since it is one of the most studied NP-hard problems. Moreover, a problem is called NP-hard if it is at least as hard as any problem in NP in the sense that any problem in NP can be polynomially reduce to a NP-hard problem. Consequently, if an algorithm solves a NP-hard problem, it can also be used to solve any other problem in NP also in a polynomial time. Furthermore, there is a class called NP-complete problems that are the NP-hard problems belonging to NP class. This last type of problems are the hardest ones in the NP class.

As suggested in the TSP, complexity theory can be applied to optimization problems such VRP since any maximization or minimization can become a decision problem. For instance, in the case of maximizing, you can wonder if there is solution whose objective value is greater than a number $X$. Since the TSP is proved to be a NP-hard problem and the VRP can be understood as *m-TSP,* that is to say, a generalization of the TSP with $m$ routes, it can be stated that the CVRP is also a NP-hard problem. Consequently, the computational resources required to solve a CVRP grows exponentially with problem size.

## 2.6 Variants

The term VRP refers to a whole set of problems whose aim is to deliver a set of customers with known demands on minimum-cost vehicle routes originating and terminating at a depot. However, depending on the problem, more constraints are needed such arrival and departure time or length of the route. Based on these restrictions, there are few variants of the VRP that are commonly used.

The variants of the VRP are mainly VRP with Time Windows (VRPTW), Backhauls (VRPB) and Pick-up and delivery (VRPPD). They all arise from the Capacitated Vehicle Routing Problem (CRVP) that is a more realistic case of the classic VRP.

In this section it can be found a brief description of every VRP variant.

### 2.6.2 Classic Vehicle Routing Problem

In the case of the classic VRP, the clients, their demand and the distances between them are known. Consequently, the aim of these kind of problems is to find a set of routes with minimum costs that fulfills:

- Every client needs to be visited just and only once.
- All routes must start and finish in the depot.

Based on the graph theory, the VRP can be defined as follows. Being $G = (V, A)$ a graph where $V = \{0, \ldots, n\}$ is the set of nodes, or clients, when the depot is located in the node 0 and the set $A$ are the arcs that connect them. For every arc $(i, j)$, $i \neq j$, it exists a non-negative cost $c_{ij}$ that normally represents the cost or travel time between nodes $i$ and $j$. Usually, these costs are represented with a matrix *C*. When *C* is symmetric it means that the cost of travelling from $i$ to $j$ is the same cost to travel from $j$ to $i$. Then, the set of arcs $A$ can be replaced for a set of edges $E$, where no directions are considered. In this case, it is assumed that there are $m$ vehicles available in the depot.

Based on its features, it can be said that a classic VRP is a TSP generalized for more than one traveler. Hence, given that TSP is a NP-hard problem, it can easily be understood that classic VRP has also been classified as a NP-hard problem.

### 2.6.3 Capacitated Vehicle Routing Problem (CVRP)

The capacitated vehicle routing problem can be considered as a classic VRP that better adapts to reality since it considers a homogeneous fleet with limited capacity. Consequently, it must be added a restriction that specifies that the sum of the demand of the clients visited in every route does not exceeds vehicle's capacity. Hence, a demand $d_i$ is assigned to every client $i$, except of the depot, that a fictitious demand $d_0 = 0$ is assigned. Moreover, in order to ensure the feasibility, it is assumed that $d_i < 0$.

As expected, the CVRP is also considered to a be a NP-hard problem.

### 2.6.4 Vehicle Routing Problem with time window (VRPTW)

The variant of the VRP considering time windows draws from the CVRP but adding the role of time. Hence, the demand must be supplied in a specific period of time, called time window. Consequently, it is not only needed to know the demand of every client and the distances between clients but also the time window of every client, the starting time of every route and the time needed to go from one client to another.

Based on the definition of the classic VRP for every client $i$ it is assigned a demand $d_i$ and for every arc $(i, j)$, $i \neq j$, it is assigned a non-negative cost $c_{ij}$. However, in the case of VRPTW it is also required to determine the time window $[a_i, b_i]$ and a service time $s_i$ for every client and also a time $t_{ij}$ for every arc $(i, j)$, $i \neq j$ to overcome the distance. Nevertheless, it is usually considered that the vehicles start their route at time 0 and the cost $c_{ij}$ and $t_{ij}$ are the same.

Consequently, the aim of this kind of problems is to find a set of routes with minimum cost that fulfills:

- Every client needs to be visited just and only once.
- All routes must start and finish in the depot.
- The sum of the clients' demands from the same routes can never exceeds vehicle's capacity.
- Clients' demand must be supplied during the considered time window.
- Vehicle stop $s_i$ units of time when supplying client $i$.

Naturally, the VRPTW is also a NP-hard problem given that it comes from VRP. It is important to highlight that VRPTW becomes a classic VRP when $a_i = 0$, $b_i = \infty$ $\forall i \in V \setminus \{0\}$ and $C = \infty$.

### 2.6.5 Vehicle Routing Problem with Backhauls (VRPB)

The variant of the VRP called VRP with backhauls also draws from the CVRP but, in this case, there are two kind of services that vehicles needs to satisfy. On one hand, vehicles must deliver products to some clients and pickup products to some others. Hence clients are divided into two groups. The first group so-called Linehaul clients $L = (1, \dots, n)$ are clients that must receipt products while the second group so called Backhaul clients $B = (n + 1, \dots, n + m)$ are clients that the vehicle must pick up products from them. Moreover, in this kind of problems there is also a provenance relation since the backhaul clients must be visited after the linehaul clients in the case that the route has the two kinds of clients.

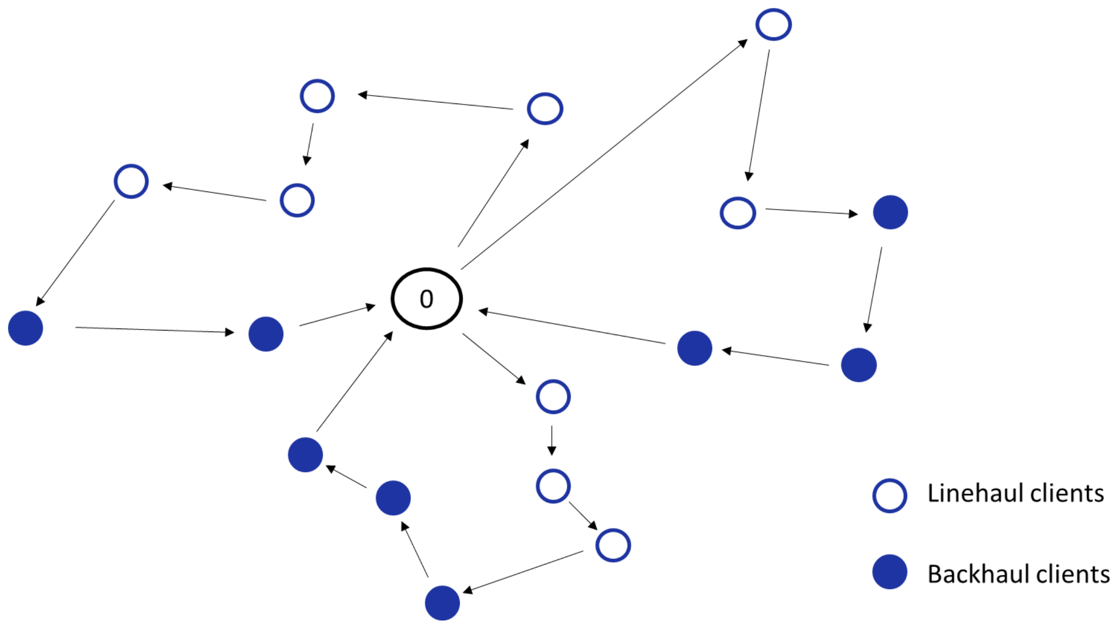


Figure 2.3. Example of Vehicle Routing Problem with backhauls.

In this case, a non-negative quantity must be delivered or picked up at every client $i$ and, as before, a fictitious demand $d_0 = 0$ is assigned for the depot.

Consequently, the aim of this kind of problems is to find a set of routes with minimum cost that fulfills:

- Every client needs to be visited just and only once.
- All routes must start and finish in the depot.

- The sum of deliveries to customers (overall Linehaul demand) and the sum of the collections of customers (overall Backhaul demand) can never exceeds vehicle's capacity.
- In case there are Linehaul and Backhaul clients in the same routes, Linehaul clients will always be visited first. Vehicle stop $s_i$ units of time when supplying client $i$.

Again, the VRPB is a HP-hard problem since it is derived from VRP. It is important to highlight that VRPB becomes a classic VRP when $B = \{\emptyset\}$.

### 2.6.6 Vehicle Routing Problem with Pickup and delivery (VRPPD)

The variant of the VRP with pick-up and delivery also draws from the CVRP. In this case, clients are allowed to send and receive products between them. Consequently, every node has a demand $d_i$ that must be delivered to other clients and a quantity $p_i$ that must be collected. However, sometimes these two factors can be combined so there is just the net effect such $d'_i = d_i - p_i$, what can also take negative values. Furthermore, it is also necessary to stablish the origin node $O_i$ and destination node $D_i$ of the demands of node $i$.

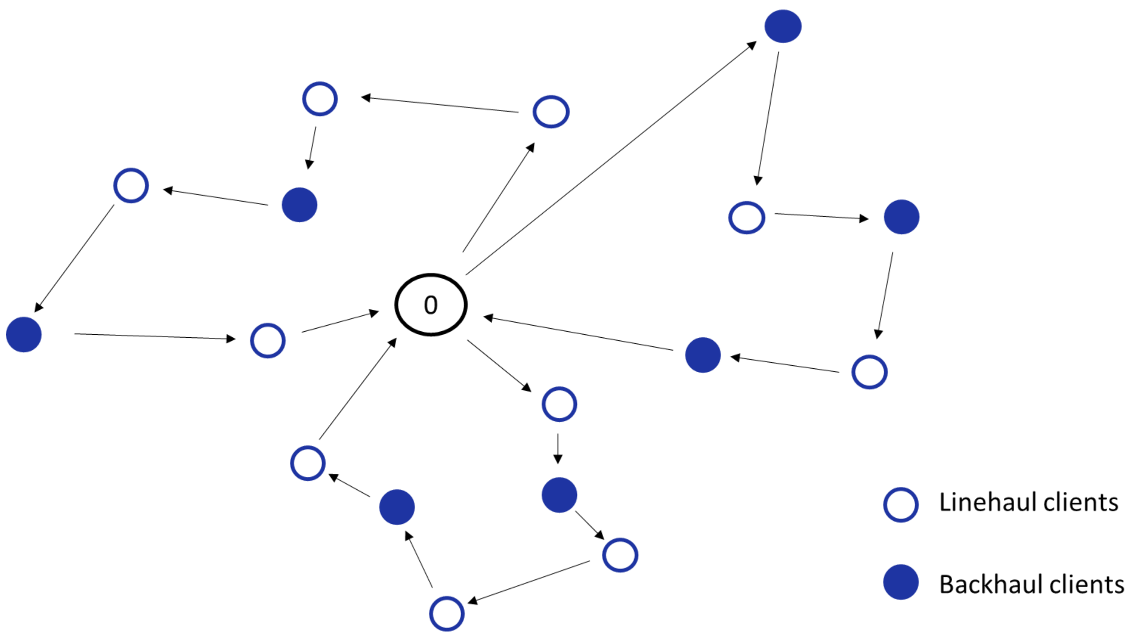


Figure 2.4. Example of Vehicle Routing Problem with pick-up and delivery.

As expected, it is assumed that the pick-up happens before the delivery. Consequently, there must be load consistency. Vehicle's load when arriving to a client is the initial load of the vehicle plus the demands collected minus the demands delivered so far.

Consequently, the aim of this kind of problems is to find a set of routes with minimum cost that fulfills:

- Every client needs to be visited just and only once.
- All routes must start and finish in the depot.
- Vehicle's load at any point of the route must be non-negative and can never exceeds vehicle's capacity.
- For any client $i$, client $O_i$, provided that is not the depot, must be visited by the same route and prior to node $i$.
- For any client $i$, client $D_i$, provided that is not the depot, must be visited by the same route and later than node $i$.

Again, the VRPPD is a HP-hard problem since it is derived from VRP. It is important to highlight that VRPPD becomes a classic VRP when $O_i = D_i = 0$ and $p_i = 0,\ \forall i \in V$.

## 2.7 Formulation

As it has previously been said, the CVRP was outlined in 1959 by Danztzig and Ramser as follows:

*A number of identical vehicles with a given capacity are located at a central depot. They are available for servicing a set of customer orders, (all deliveries, or, alternatively, all pickups). Each customer order has a specific location and size. Travel costs between all locations are given. The goal is to design a leastcost set of routes for the vehicles in such a way that all customers are visited once and vehicle capacities are adhered to.*[27]

Given a graph $G = (V, A)$ a where $V = \{0, \ldots, n\}$ is the set of clients, when the depot is located in the node 0 and set $A$ the set of arcs that connect them. For every arc $(i, j), i \neq j$, it exists a non-negative cost $c_{ij}$ that represents the cost to overcome the distance between nodes $i$ and $j$. Moreover, $K$ is the number of available vehicle that can be used, $w_i$ a non-negative demand of client $i$ and $Q$ vehicle's capacity. The formulations described below regard to an asymmetric problem. If a symmetric problem is considered, some simplifications can be done.

### 2.7.1 Two-index formulation

The formulation is based on just one set of binary variables $x_{ij}$ that takes value 1 if the arc $(i, j) \in A$ is used; otherwise, it takes value 0. Consequently, it uses $O(n^2)$ binary variables.

Hence, the problem is outlined as follows:

Objective function:

$$min \sum_{i \in V} \sum_{j \in V} c_{ij} \cdot x_{ij} \tag{2.1}$$

Subject to:

$$\sum_{j \in V} x_{ij} = 1, \forall i \in V \setminus \{0\} \tag{2.2}$$

$$\sum_{i \in V} x_{ij} = 1, \forall j \in V \setminus \{0\} \tag{2.3}$$

$$\sum_{i \in V} x_{i0} = K \tag{2.4}$$

$$\sum_{j \in V} x_{0j} = K \tag{2.5}$$

$$\sum_{i \notin S} \sum_{j \in S} x_{ij} \geq r(S), \forall S \subseteq V \setminus \{0\}, S \neq \emptyset \tag{2.6}$$

$$x_{ij} \in \{0,1\}, \forall i, j \in V \tag{2.7}$$

Restrictions (2.2) and (2.3) establish that just one arc must enter and leave every client, respectively. Similarly, restrictions (2.4) and (2.5) establish that there must be $K$ vehicles arriving and leaving from the depot. Constraints (2.6) and (2.7) are called Capacity-Cut

Constraints (CCC).

#### 2.7.1.1 *Capacity-Cut Constraints (CCC)*

The set of CCC play two roles at the same time since they impose connectivity and also constraints regarding vehicle capacity. Equation (2.6) outlines that each cut $(V - S, S)$ defined by a set of clients $S$ is crossed by a number of arcs that cannot be smaller than the minimum number of vehicles *r(S)* needed to serve customer in *S*. Since the demand of customers in set $S$ can be expressed as $d(S) = \sum_{i \in S} w_i$, *r(S)* can be replaced by the lower bound $\lceil d(S)/Q \rceil$, that represents the minimum number of vehicles *r(S)* needed to supply clients in *S*.

However, two alternative formulation for restriction (2.6) can be found replacing the capacity cut constraints by generalized subtour elimination constraints.

Before delving into the alternative, the subtour elimination issue must be introduced.

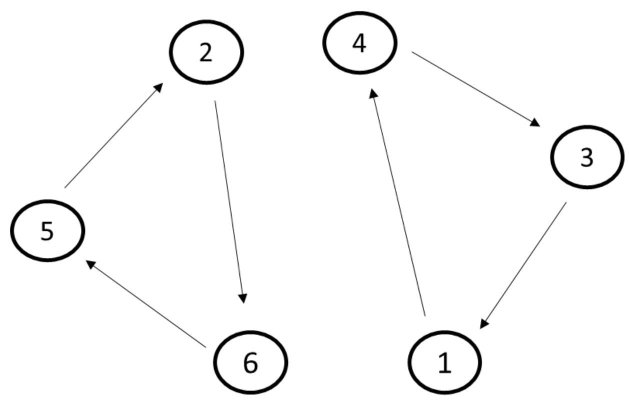


Figure 2.5. Example of subtour in a TSP.

Let's assume that just one route is considered, as if it would be a TSP. Without considering restriction (2.6) the situation described in Figure 2.5 could take place since it fulfills all other restrictions. Based on Figure 2.5 it can be seen the subset W = {1, 4, 3}, for instance, has three arcs that connects the nodes. If the amount of arcs is limited to 2, this situation could never happen. In order to model this last restriction, it is needed some new sets:

$$\forall W \subset V, A(W) = \{a = (i,j) \in A: i,j \in W\} \tag{2.8}$$

$$\delta^{-}(W) = \{a = (i,j) \in A: i \notin W, j \in W\} \tag{2.9}$$

$$\delta^{\mp}(W) = \{a = (i,j) \in A: i \in W, j \notin W\} \tag{2.10}$$

Consequently, the subtour elimination set of constraints could be written as

$$\sum_{i \in S} \sum_{j \in V} x_{ij} \leq |W| - 1, \forall W \subset V \tag{2.11}$$

Equation (2.11) can also be outlined as equation (2.12) what stablishes that for any subset *W* of clients it must be at least one arc that leaves the subset.

$$\sum_{i \notin S} \sum_{j \in S} x_{ij} \geq 1, \forall W \subset V \tag{2.12}$$

The concept just explained regards to just one route. However, equation (2.11) becomes equation (2.13) when more routes and a depot is considered. Since it outlines that at least *r(S)* arcs leave the customer set *S*.

$$\sum_{i \in S} \sum_{j \in V} x_{ij} \leq |S| - r(S), \forall S \subseteq V \setminus \{0\}, S \neq \emptyset \tag{2.13}$$

Actually, set of restrictions (2.13) is the first alternative of restriction (2.6). Consequently, generalized subtour elimination constraints can act as an alternative of the capacity-cut constraints.

It is important to highlight that restrictions (2.6) and (2.8) have a cardinal that exponentially increases with $n$, that is to say, the number of clients to be visited. Therefore, it is practically impossible to directly solve the integer lineal problem.

Consequently, another alternative with polynomic cardinal can be defined. For that, an additional continuous variable $u_i$ is needed, whose value represents the load of the vehicle after visiting node $i$.

$$u_i - u_j + Q \cdot x_{ij} \leq Q - w_j, \forall i, j \in V \setminus \{0\}, i \neq j \tag{2.14}$$

$$w_i \leq u_i \leq Q, \forall i \in V \setminus \{0\} \tag{2.15}$$

It can easily be noticed that restrictions (2.14) and (2.15) represent the capacity and connection constraints of the CVRP. In fact, when $x_{ij} = 0$, equation (2.14) is redundant; otherwise, it imposes that $u_j \geq u_i + w_j$, so possible subtours are eliminated.

This formulation is useful when the cost of the solution depends on the arcs used. However, when the solution also depends on the sequence of visit, an alternative must be found.

### 2.7.2 Three-index formulation

The three-index formulation is useful when dealing with problems whose solution depends on the sequence of visiting nodes or on the kind of vehicle assigned to every route. This is because the formulation explicitly specifies the vehicle that visits every client by using three-indexes. However, as a counterpart, this formulation comprises much more variables since it has $O(Kn^2)$ binary variables with the form of $x_{ij}^k$ that takes value 1 if the arc $(i, j) \in A$ is visited by vehicle $k$; otherwise, it takes value 0. Moreover, it is needed to specify if the node $i$ is visited by vehicle $k$, what is represented by the binary variable $z_i^k$. The variable takes a value of 1 if vehicle $k$ visits node $i$, otherwise it is 0. Therefore, the number of variables is not just $O(Kn^2)$ but it is also needed to add $O(Kn)$ variables.

Hence, the problem is outlined as follows:

Objective function:

$$min \sum_{i \in V} \sum_{j \in V} c_{ij} \cdot \sum_{k=1}^{K} x_{ij}^k \tag{2.16}$$

Subject to:

$$\sum_{k=1}^{K} z_i^k = 1, \forall i \in V \setminus \{0\} \tag{2.17}$$

$$\sum_{k=1}^{K} z_0^k = K \tag{2.18}$$

$$\sum_{j \in V} x_{ij}^k = \sum_{j \in V} x_{ji}^k = z_i^k, \forall i \in V \setminus \{0\}, \forall k = 1, \dots, K \tag{2.19}$$

$$\sum_{j \in V} w_i \cdot z_i^k \leq Q, \forall k = 1, \dots, K \tag{2.20}$$

$$\sum_{i \notin S} \sum_{j \in S} x_{ij}^k \geq z_h^k, \forall S \subseteq V \setminus \{0\}, h \in S, \forall k = 1, \dots, K \tag{2.21}$$

$$x_{ji}^k \in \{0,1\}, \forall i, j \in V, \forall k = 1, \dots, K \tag{2.22}$$

$$z_i^k \in \{0,1\}, \forall i \in V, \forall k = 1, \dots, K \tag{2.23}$$

Restrictions (2.17), (2.18) and (2.19) stablish that every client must be visited just and only once by the vehicle that it has been assigned to it, that *K* vehicles leave the deposit and, finally that the same number of vehicles, that is to say one, arrives and departures from every node. Moreover, the set of constraints (2.20) represent the vehicle's capacity constraints. Finally, the set of constraints (2.22) represent the capacity-cut constraints and subtour elimination constraints.

Similarly, as two-index formulation, the set (2.21) can be described as (2.24) and (2.25) and (2.26).

$$\sum_{i \in S} \sum_{j \in V} x_{ji}^k \leq |S| - 1, \forall S \subseteq V \setminus \{0\}, |S| \geq 2, \forall k = 1, \dots, K \tag{2.24}$$

$$u_i^k - u_j^k + Q \cdot x_{ji}^k \leq Q - w_j, \forall i, j \in V \setminus \{0\}, i \neq j, \forall k = 1, \dots, K \tag{2.25}$$

$$w_i \leq u_i^k \leq Q, \forall i \in V \setminus \{0\}, \forall k = 1, \dots, K \tag{2.26}$$

When equations (2.25) and (2.26) are used it is already represented the capacity constraints, so the set (2.20) is no longer needed.

It is important to highlight again the large number of variables that this formulation uses. Therefore, if it is not explicitly needed, the formulation with two-indexes is usually more suitable.

## 2.8 Resolution method

Complexity theory has proved the difficulty in solving problems like VRP. Hence, in order to find a solution for VRP, there are mainly two strategies. On one hand, CVRP can be optimally solved by using exact methods although it may take long time or either find an approximate method or heuristic that will provide a fast although not optimal solution.

The first part of this section focuses on how to find the optimal solution for the CVRP whereas the second part focuses on heuristic methods.

### 2.8.1 Optimal Solution

One of the well-known methods to optimize large scale problems is the Brunch and Bound algorithm.

The algorithm consists in dividing the search space into subspaces in a tree form, so called branching. Every subspace is evaluated so the lower and upper bounds are found, what is also called bounding. When the bounds are determined and it is proved that the subspace does not contain the optimal solution found so far, the subspace is ruled out, what is also called pruning. If the subspace contains the optimal solution found so far, the subspace is branched and bounded again, as an iterative procedure. Finally, when the difference between lower and upper bounds, called gap, is small enough it can be said that the optimal solution has been found.

Usually, the lower bound is estimated by solving a relaxed problem. Hence, some of the constraints of the problem are removed. Based on the constraints removed, the lower bound obtained is different. Consequently, the quality of the lower bound is essential to find in a faster way a solution for the problem raised. In this sense, there are several approaches to improve the lower bounds. However, this dissertation will not focus on these techniques.

### 2.8.2 Heuristics

As it has previously been said, finding the optimal solution in large scale problems it is nothing but difficult. Hence, heuristics play an important role to provide quick and near-optimal solutions. It is important to note that heuristics can be considered a search procedure that iteratively generates and evaluates candidate solutions. Hence, how to effectively, intelligently and efficiently search for good solutions is the key to the success of a heuristic.[34]

There are mainly three groups of heuristics: constructive heuristics, improvement heuristics and metaheuristics.[25] The first group, constructive heuristics, build a solution that fulfills the problem constraints very fast. However, often the solution found is not very good. Hence, improvement heuristics draw from complete solution and apply techniques that modify it so a better solution it is found. The third type of heuristics are called metaheuristics and are a kind of more sophisticated heuristics with emphasis on performing a deep exploration of the most promising regions of the solution space.[33] However, this dissertation will not focus on this kind of heuristic.

#### 2.8.2.1 *Route Construction*

Route construction heuristics can be further divided into three classes: savings heuristics, insertion heuristics and two-phase heuristics.[33] In this section it will be explained a saving heuristic and also a two-phase heuristic.

- Clark and Wright Algorithm

One of the most known savings heuristics for solving the CVRP is the algorithm developed by Clarke and Wright in 1964[4] which assumes no restriction in the number of vehicles available. The algorithm starts with $(n - 1)$ routes, one for every client. Afterwards, it merges different routes so the savings obtained are the greatest ones, whenever it is possible for capacity constraints.

The steps that must be followed to apply the algorithm are the following:

1. Begin with an unfeasible solution in which every customer is supplied individually by a separate vehicle.
2. Combine any two of these single customer routes to use one less vehicle and reduce total cost. Combining $i$ and $j$ results in cost savings $s_{ij} = c_{i0} + c_{0j} - c_{ij}, \forall i, j = 1, \ldots, n$
3. Select the arc $(i, j)$ with maximum saving subject to the requirement that the combined routes is feasible (i.e. does not exceed vehicle capacity)
4. Repeat the process until the number of routes is reduced to $K = \left|\sum_{j \in V} w_j / Q\right|$, being $Q$ the capacity of the vehicle and $w_j$ the demand of node $j$.

Given that it is a heuristic, the solution obtained is not the optimal one. However, it uses the given time $O(n^2 \log(n))$ to solve the problem. Nevertheless, an intensive research has been made to improve the efficiency, effectiveness and accuracy of the savings heuristic.[33]

It is important to highlight that the algorithm assumes no restriction in the number of vehicles available. However, if number of vehicles *K* is fixed, when reached this number, step 3 can be repeated although negative savings are found.

- Fisher and Jaikumar algorithm

One of the most known two-phase heuristics for solving the CVRP is the algorithm developed by Fisher and Jaikumar in 1981.[17] Since it is a two-phase algorithm, the problem is decomposed into two steps:

1. Clustering of nodes into feasible routes
2. Actual route construction

Particularly this algorithm solves a Generalized Assignment Problem (GAP) to form the clusters and it assumes that the number of vehicles *K* is fixed.

The steps that must be followed to apply the algorithm are the following:

1. Choose randomly seed points $j_k$ in $V$ to initialize each cluster $k$.
2. Compute the cost $d_{ik}$ of allocating each customer $i$ to each cluster $k$

$$d_{ij_k} = \min\{c_{0i} + c_{ij_k} + c_{j_k 0}, c_{0j_k} + c_{j_k i} + c_{j_k 0}\} - (c_{0j_k} + c_{j_k 0}))$$

   Being $c_{ij}$ the cost of travelling from $i$ to $j$.

3. Solve a GAP with costs $d_{ik}$, customer demands $w_j$ and vehicle capacity $Q$.
4. Solve a TSP for each cluster corresponding to the GAP solution.

A great advantage of this method is that in step 1, the choice is random. Hence, every time that the algorithm is run, a different solution is obtained. Consequently, if it is executed enough times, solutions obtained can be quite good. In any case, the algorithm presents a big disadvantage since it needs to be solved a TSP, what is a NP-hard problem.

#### 2.8.2.2 *Improvement heuristics*

When a solution is obtained by means of an heuristic method, some modifications can be applied in order to improve its quality. There are a lot of different improvement methods but they can be classified into two groups. On one hand, if just one route is modified at a time, the operator is called intra-route operator. On the other hand, when more than one route is modified at a time, operators are called inter-route operators.

One of the well-known operators was outlined by Lin in 1965,[31] so called λ-opt (optimization) operator. It is an intra-route operator that removes λ edges from a route and reconnects the segments in a complete new way. However, for higher values of λ, higher computational time required. Hence, $\lambda = 2$ and 3 are the most used values.

Further details or inter-route operators or some other improvement heuristics can be found at [25].

# Chapter 3: Firm and current distribution of products

## 3.1 Introduction

In this chapter, the focus relies on the firm insight and its current logistics to deliver products in Shanghai. Hence, the chapter starts with some information of the company and its market. Moreover, the chapter focuses in the current distribution, its warehouse and its operation.

## 3.2 Family Mart company

Family mart is a convenience store franchise chain launched on 1981 in Japan. During the first years, the company focused on consolidate its business in Japan and afterwards, in 1988 it started to expand to Taiwan. Thereafter, the company expanded to many more countries: Thailand (1992), China (2004), Vietnam (2011). Indonesia (2012) Philippines (2013) and Malaysia (2016). Hence, Nowadays, there are 24243 stores worldwide in Japan, Taiwan, China, Philippines, Thailand, Vietnam, Indonesia and Malaysia.[9]

Regarding China, Family Mart brand officially entered the Chinese market in 2004 in Shanghai and began the business in mainland China. However, currently it is already established in Shanghai, Guangzhou, Suzhou, Hangzhou, Chengdu, Wuxi, Shenzhen, Beijing, Dongguan and Jiaxing.[26]

Family mart stores are small franchises that mainly offer goods such basic grocery, take away food, drinks, bento, magazines and drugstore products. Approximately, every Family Mart has 400 different Stock Keeping Units (SKU). It is interesting to note that Family Mart has its own white label brand.


Figure 3.1. Family Mart store.

There are several aspects that assure its success. First of all, there are a lot of Family Mart stores. Approximately, one store covers 3000 people. Hence, usually one can reach a store in less than 10 minutes walking. Moreover, opening hours are very convenient so in case of an urgency, there is always a Family Mart nearby. Furthermore, although it is not a big supermarket, it always meets the basic needs of customers since one can find the basic and essential products. Finally, there are also service facilities such ATM or phone recharge that makes Family Mart stores differ from other supermarkets.

Figure 3.2. Type of products sold in a Family Mart store.

In order to deal with the distribution to Family Mart stores, there are three main sites: the management center, Pudong Logistic Warehouse and Fengxian Logistic Warehouse. Both warehouses are supplying products to Family Mart stores. In fact, Pudong warehouse distributes products to 464 Family Mart stores while Fengxian warehouse distributes products to 610 stores. However, their distribution range is different. In this dissertation, just Pudong Logistic Warehouse is considered, so Fengxian warehouse is out of the scope.

Pudong warehouse is distributing products to three different areas in Shanghai: Hongkou, Huangpu and Pudong. It supplies products to 60 stores in Hongkou, 93 stores in Hangpu and 311 stores in Pudong. The total number of stores increased in few time from 315 to 464 stores, with a peal supplying amount of 14 million.[7]

Pudong Logistic Warehouse is, at the same time, dealing with three more types of products from NSK, Unicharm and Shisiedo. NSK is a world's leading manufacturers of bearings, linear technology and steering systems.[35] Moreover, Unicharm is a Japanese company that manufactures disposable hygiene products, household cleaning products, specializing in the manufacture of diapers for both babies and adult incontinence, feminine hygiene products and pet care products.[13] Finally, Shiseido offers products in brightening and anti-aging skincare, makeup and fragrance.[38] However, the three business are out of the scope of the dissertation.

## 3.3 Pudong Logistic Warehouse

Pudong Logistic Warehouse, launched on the 27th of April 2016 is located in Longdong Avenue 3569 in Pudong New Area, Shanghai. There are 2,542m$^2$ dedicated to the whole operation. More specifically, 1289m$^2$ dedicated to refrigerated products and 693m$^2$ to frozen products as seen in Figure 3.3. Since the two kinds of products need different storage characteristics, two areas are confined areas. The area dedicated to frozen products is at -19ºC.

Pudong Logistic Warehouse is run my one business manager and 2 on-site supervisors. The business manager is responsible of 3 people and on-site supervisors are responsible of 37 other people, most of them doing sorting activities. However, out of the 43 workers, 35 workers are outsourced, most of them, doing the on-site operations.

Furthermore, there are a lot of quality standards that need to be satisfied. In order to ensure high quality in the operation of the warehouse, several actions such KPI and regular meetings are carried out.

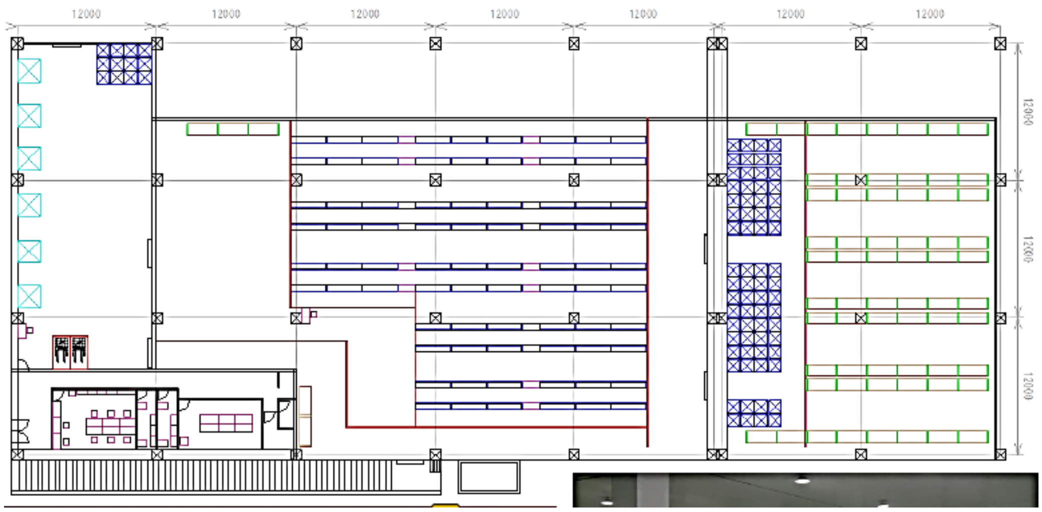

Figure 3.3 Layout of Pudong Logistic Warehouse.

## 3.4 Warehouse operation

As explained, the warehouse is responsible of all the operations of receiving the products, sorting and delivering them to the 464 Family Mart stores. Consequently, the warehouse receives products in a daily basis from 50 different suppliers. For that, 12 trucks arrive per day to deliver frozen products to the warehouse and 34 other trucks arrive for delivering refrigerated products. Every day the warehouse receives 250.000 frozen units and 160.000 refrigerated units. The greatest proportion of frozen products are received in the morning. Regarding refrigerated products, the last ones are received before 4pm. However, the peak hours of receiving products is between 11 and 12am.


Figure 3.4 Unloading frozen products.

Hitachi company is responsible to deliver an average volume of 900 pieces per day to each store. Consequently, the warehouse deals with an average monthly volume of 11.500.000 pieces per month. However, the processes and operations regarding refrigerated and frozen products are different.

Figure 3.5 Sorting activities in Pudong Logistic Warehouse

When refrigerated products arrive to the warehouse, they are inspected and, on the same day, they are sorted and ready to be shipped by 2T or 3T trucks. Therefore, there is no storage of the products because everything happens in 24h. It is important to note that every truck can carry 200 blue plastic boxes, the ones that can be seen in Figure 3.6.

Figure 3.6 Plastic boxes used to deliver refrigerated products to Family Mart stores.

On the other hand, when frozen products arrive to the warehouse, they are inspected and stored. Depending on the products they are going to spend more or less time stored. However, they spend at most 2 weeks in the warehouse. Afterwards, products are sorted and ready to be shipped also by 2T or 3T trucks to the 464 stores in Shanghai. Consequently, every Family Mart store receives one deliverable of refrigerated and another one for frozen products.

Since there is storage of frozen products but not of refrigerated products, there are 486 locations for frozen products and 40 locations for refrigerated products.

The shipment of frozen products is flexible. However, the shipment of refrigerated products takes place between 4pm and 9.30pm. Every day there are 5 batches to different destinies, so approximately, at every departure, 10 trucks depart to different directions. The fleet of trucks is 2T or 3T trucks, since heavier trucks are not allowed to run in the city. Moreover, there are approximately between 50 to 55 vehicles used to distribute refrigerated products.

# Chapter 4: Problem definition

## 4.1 Introduction

In this chapter, the problem to be solved and its main features is outlined. Hence, the chapter starts with the description of the problem and the assumptions and hypothesis taken. Moreover, the chapter presents the data that has been provided in order to solve the problem and its treatment.

## 4.2 Problem description

The problem that needs to be solve regards the distribution of refrigerated products to more than 450 Family Mart stores. As it has previously been said, Family Mart is not responsible of the distribution of its products in Shanghai but the service is outsourced to Hitachi Transport Systems S.L. Hitachi company uses a warehouse located in the south-east side of Shanghai, Pudong Logistic Warehouse, as the base of their performance.

Although the warehouse is responsible for distributing refrigerated and frozen products to the stores, both distributions processes are isolated since the service that needs to be provided is quite different. Hence, this dissertation only assesses the distribution of refrigerated products, frozen products are out of the scope.

In order to operate the distribution of refrigerated products to all Family Mart stores, Hitachi company owns a fleet of trucks of 2T or 3T with specific features in order to transport refrigerated products. When all the operations in the warehouse are done and the trucks are filled with boxes full of products, trucks leave the warehouse to visit a set of Family Mart stores.

It is important to note that Hitachi Transport Systems performs all the stages of the distribution, starting from the definition of its routes to the distribution itself. In order to define the routings of the fleet of vehicles based on the demand of every Family Mart store, Hitachi uses a Transport Management System (TMS) software capable to solve complex systems. However, it is interesting to understand what is in the black box of these kind of software so the problem could also be solved without its use.

Based on this idea, the problem raised in this dissertation is to find a mathematical formulation to model the distribution of refrigerated products from the warehouse to the more than 450 Family Mart stores. Hence, the problem is not just proposing a mathematical formulation but also implementing it, so a good routing distribution can be given.

Since the problem is to find the optimal or near optimal routes to deliver a given demand to a set of customers with the minimum cost, the problem can be understood as a Vehicle Routing Problem with some constraints. However, Hitachi's vehicles fleet are homogeneous and have a limited capacity. Hence, capacity constraints must be taken into account, so a Capacitated Vehicle Routing Problem must be solved. Moreover, Hitachi first stablishes the routes and then it notifies to every shop the expected arrival time. However, in this dissertation, the importance of having schedule is also considered. Hence, the effect of a fixed arrival time or between a given time window is also addressed. Consequently, instead of a Capacitated Vehicle Routing Problem, it can be stated that the problem raised is a Time Window constrained Capacitated Vehicle Routing Problem.

In the following section there is a brief description of the hypothesis and assumptions taken in order to outline the scope and better define the problem explained.

## 4.3 Hypothesis and assumptions

Minimizing the transportation cost is one of the essential elements of the problem. Hence, the features that characterize the cost must be clearly outlined. The cost is defined by units of time, that is to say, minutes. On one hand, there is a variable cost that depends on the amount of time the vehicle is used, the amount of time needed to overcome all routing distance. On the other hand, there is a fixed cost per vehicle used. Consequently, if more vehicles are used, a higher total cost results. This fact will force the model to put more clients in a same route so a vehicle is not visiting just few stores. It is important to note that the resulting units in time will not be the amount of time needed to supply all the demand, it will be just a unit of measurement.

Moreover, as noted before, the fleet used to operate the distribution is a fleet of 2T and 3T trucks thermally isolated, so suitable to transport refrigerated products. However, it is assumed a homogeneous fleet of trucks with 200 blue plastic boxes per truck of capacity. Moreover, the garage for the fleet is located in the same warehouse, so all vehicles start and finish the routes at the same place, the depot.

In every Family Mart store, the vehicle delivers some boxes full of products and picks up empty boxes. The number of boxes delivered depends on the demand of every store. However, the number of boxes that the vehicle picks up is the same number of boxes that it delivers. Consequently, it can be stated that at every shop there is an exchange of full and empty boxes. In any case, since the delivering boxes have a fix volume, as seen in Figure 3.6, the volume of the truck occupied is the same during the whole route.

This fact implies that the problem can be understood as delivering boxes full of products or picking up empty boxes. Nevertheless, the result must be the same. For modelling purposes, it has been assumed the second option, that is to say, the vehicle goes store by store picking up empty boxes. Consequently, the amount of boxes collected at the first instant, in the depot, is zero and, therefore, it is assumed that the vehicle leaves the warehouse empty. The vehicle goes collecting empty boxes, or what is the same, delivering full boxes when visiting stores. Consequently, the load of the vehicle starts at zero in the depot and it increases when visiting stores. However, in any case, the load of the vehicle must be lower than vehicle's capacity.

Furthermore, every Family Mart has a different daily demand that needs to be satisfied so that all stores must be visited daily. Moreover, it is assumed that the demand is required at a specific time. However, given that in the real world it is very difficult to fulfill fixed time requirements, it is usual to stablish a time window, that is to say, a period when the demand can be supplied.

Time window can be expressed as $[a, b]$ so that a vehicle must arrive before $b$. Moreover, it can arrive before $a$ but the customer will not be served before $a$. Consequently, the service time is between $a$ and $b$. For modelling purposes, if a node $i$ requires the demand at time $d_i$, the time window considered is $[d_i - D, d_i + D]$, being $D$ a parameter stablished for every instance solved.

Moreover, it is important to highlight that the service time at every Family Mart store has been considered negligible. Consequently, the moment a vehicle arrives to a node to deliver products is the same as the vehicle departs from it. This assumption has a small impact on the results when the time plays an important role. Otherwise, when there are no restrictions regarding time, this assumption is redundant.

Last but not least, note that in this dissertation words routes and vehicles are used indistinctively.

## 4.4 Data provided

In order to properly understand the problem and its features, some data must be collected. After visiting Hitachi's warehouse, some data was provided.

First of all, they provided a list the 467 stores the warehouse is supplying products to. Every store was identified with a number and a name. For instance, if a store is located in the street 博山路 (Bó shān road), the name of the store is 博山路店, that is to say, Bó shān road shop. This information is essential in order to locate the stores. However, as explained in Chapter 2: , what is exactly needed are the distances or travel times between stores. Consequently, the data needed to be treated in order to be useful. The treatment of the data is described in 4.5.2

Moreover, Hitachi also provided two existing routing. For every routing they provided the number of vehicles used, the stores visited by every vehicle and also the sequence of the stores visited. In the first route, 33 vehicles where used while in the second route just 25 where used in order to supply all the demand.

As previously noted in Section 3.4 first stablishes the routes and then it notifies to every shop the expected arrival time. Consequently, given the routes and knowing where are the stores located, the schedule defined is not very relevant.

Finally, an important fact is the demand of every store. Since it is confidential data, the demand was not provided. However, given the information explained in the warehouse visit, described in Chapter 3: , an approximated average demand could be extracted.

## 4.5 Data treatment

As introduced in the previous section the data provided is not exactly the data needed. Consequently, some data treatment is necessary. The data needed to develop the model is further explained in Section 5.2.1 . However, it can already be stressed that the distances or travel time between stores is essential for any formulation or heuristic method.

Based on the store's name, the first step that must be done is to find the location. Afterwards, when all locations are found, the distances between stores can be calculated. The procedure followed in order to obtain the location of all Family Mart stores is developed in Section 4.5.1. Section 4.5.2 outlines the second step of the data treatment, building the distance and travel time matrix.

### 4.5.1 Locations

It is essential to determine the location of every Family Mart store. Given the large amount of Family Mart stores in Shanghai, a methodic process was needed.

Before getting closer to the procedure, it is important to note that one of the biggest obstacle to overcome in this phase was the language. As expected, all the names of the stores and consequently their locations are written in Chinese. However, having to work with data uncapable to understand, it makes one be, besides a slave of the translator, less productive.

In any case, they provided a list the 467 stores with a number and a name. The name represents the street where the store is located. In the case there are more than one shop in the same street, the stores are numbered such 赤峰路站店 and 赤峰路站二店.

The first step of the process consisted on searching in the Family Mart website.[16] There is a section in the website devoted to search Family Mart stores. Consequently, the first step consisted in introducing the name provided in the searching tool and, in case the store was found, draw its location. After searching 467 stores, just 347 locations were found.

However, before moving to the second step, the stores were located in a map using *mymaps* application from google maps. This first step is very important since, once some stores are placed in a map, the problem begins to take shape.

Since 120 still needed to be situated, further steps were needed. It could happen that it existed a Family Mart store but the provided was not exactly the one used in the website. Consequently, the second step consisted in searching, one by one, the street of the shop in the map of Family Mart website and compare it with the map resulting of step one. In the case a store is located in the street but it has not been considered in step one, the direction of the store was collected in the addresses list and the store was also added in the map. Moreover, it is important to say that in the case the street is very short, that is to say, shorter than one kilometer, an approximated location is used. After applying the step for the 120 stores that were still missing, 50 store locations were found. Consequently, just 70 more locations needed to be found. Needless to say, when a new store location is found, the map is updated so it is always up to date.

The third step of the process is similar to step one but using another searching tool. This time, instead of using Family Mart store, Gaode map[1] is used. The name provided is introduced to the searching tool so that the location of some stores is obtained. In fact, out of the 70 missing stores, 35 new locations could be placed in the map.

The fourth and final step of the process is similar to the second step but using Gaode map. The whole city is examined, neighborhood by neighborhood, comparing the stores in Gaode map and the stores already located. In case it is found a store that has not been located yet, its locations is compared with the street names of the stores missing. If the street is located in the area, the store is added in the scope of the project and the map is updated. After this step, 18 new locations were found so just 17 locations were missing.

Hence, after the whole process, 450 Family Mart stores were located. The stores observed in Figure 4.1 are the stores that conform the scope of the dissertation

It is important to note that sometimes there is more than one store located in the same place. For instance, in Pudong International Airport, there are more than 2 Family Mart stores. There are 17 locations with 2 stores, two locations with 3 stores and 1 location with

4 Family Mart stores. This fact cannot be appreciated in the map of Figure 4.1 since dots overlap.

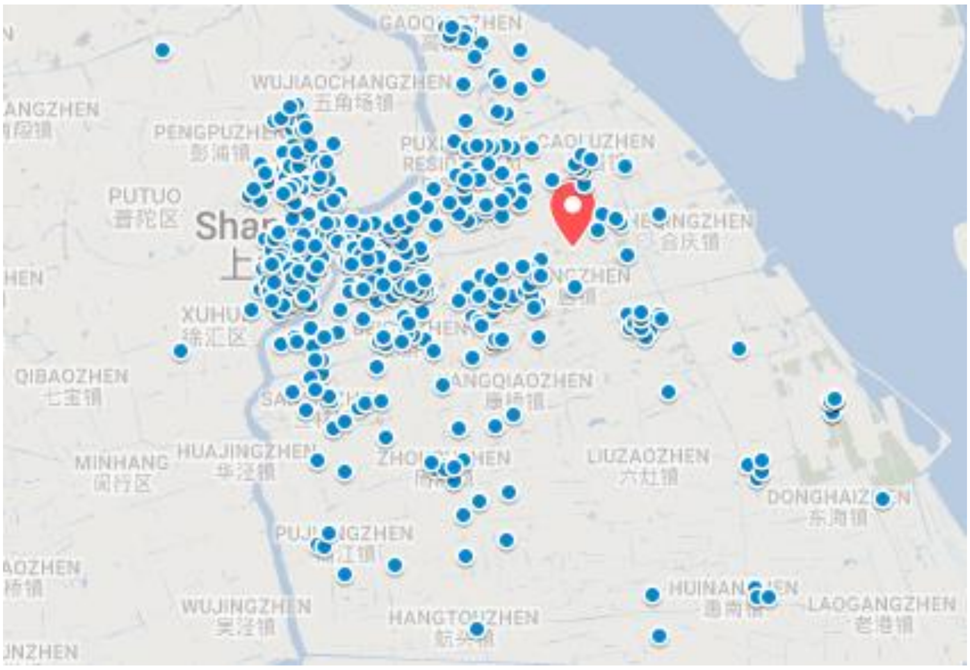


Figure 4.1 Map of the 450 stores considered. The red point is Pudong Logistic Warehouse

### 4.5.2 Travel time and distance matrix

Once all the stores are located, it is time to build the distance and travel time matrix. If the amount of distances and time needed would not be really large, google maps site could be used in order to find one by one all the times and distances. However, given that 450 stores are considered, this method is completely unfeasible. In fact, when the depot is considered, the distance and time matrixes' size are $451 \cdot 451$, so 203401 elements are needed to be found for every matrix.

Some research was done and a possible method to obtain all the values is by means of Google Maps Geo-Location APIs. A lot of business make use of some of Google APIs for the wide range of services available. Google API's is a set of application programming interfaces (APIs) developed by Google which allow communication with Google Services and their integration to other services such Google Maps.[10] One of the services that it is offered is the Distance matrix API, which allows to plan distances between points with up-to-date data and estimated real time traffic. Hence, deliver travel time and distances for one or more locations, exactly what was needed for the project.

In order to use the API, the first step is to understand its performance. With a short code, google API provides a response with detailed information regarding distance and time. An example of the response can be seen in Figure 4.2, where the distance and travel time between Vancouver and San Francisco is found.

```
<?xml version="1.0" encoding="UTF-8"?>
<DistanceMatrixResponse>
 <status>OK</status>
 <origin_address>Vancouver, BC, Canada</origin_address>
 <destination_address>San Francisco, CA, USA</destination_address>
 <row>
  <element>
   <status>OK</status>
   <duration>
    <value>53778</value>
    <text>14 hours 56 mins</text>
   </duration>
   <distance>
    <value>1528699</value>
    <text>1,529 km</text>
   </distance>
  </element>
 </row>
</DistanceMatrixResponse>
```

Figure 4.2 Example of the Google API response.

Consequently, if the origin and destination could be generalized as a variable, the process could be automatized. In order to do so, an excel file can be linked to the API using the excel option *obtain data from external sources*. Hence, this option has been used in order to link excel with google map API. Moreover, the code is modified so instead of a single origin and destination, it could be a variable. The variable takes the values of some columns of the excel so the code is run with different origins and destinations. Finally, the code can also be modified so the results are delivered in the excel with the units desired.

An example of the excel file input and output can be seen in Figure 4.3 and Figure 4.4, where the distance between origins and destinations is expressed in kilometers and the time expressed in hour format.

| Start_Adress | Start_City | Start_State | Start_Country | End_Adress | End_City | End_State | End_Country |
|---|---|---|---|---|---|---|---|
| 浦电路337号 | Shanghai | Shanghai | China | 芳华路511号 | Shanghai | Shanghai | China |
| 东方路912号 | Shanghai | Shanghai | China | 莲溪路508号 | Shanghai | Shanghai | China |
| 张杨路1041号 | Shanghai | Shanghai | China | 五星路364号 | Shanghai | Shanghai | China |
| 张扬路2057号 | Shanghai | Shanghai | China | 莲园路路190号 | Shanghai | Shanghai | China |

Figure 4.3 Example of the input of the calculation file.

| Start Adress | Start City | Start State | Start Country | End Adress | End City | End State | End Country | Distance (Km) | Time (hh:mm:ss) |
|---|---|---|---|---|---|---|---|---|---|
| 浦电路337号 | Shanghai | Shanghai | China | 芳华路511号 | Shanghai | Shanghai | China | 7.086 | 0:14:55 |
| 东方路912号 | Shanghai | Shanghai | China | 莲溪路508号 | Shanghai | Shanghai | China | 8.29 | 0:18:45 |
| 张杨路1041号 | Shanghai | Shanghai | China | 五星路364号 | Shanghai | Shanghai | China | 12.134 | 0:18:50 |
| 张扬路2057号 | Shanghai | Shanghai | China | 莲园路路190号 | Shanghai | Shanghai | China | 10.083 | 0:15:19 |

Figure 4.4 Example of the output of the calculation n file

By this method, all the travel times and distances between the stores can be found. However, there is also some disadvantages.

The first drawback comes from the fact of being located in China. In order to access any Google service, every user must make use of a VPN. Moreover, Google APIs is a private service offered by Google, so it is not free. Overall cost of building the travel time and distance matrixes is 185.17€ (approximately 1390 RMB). However, a free trial with a budget of 254.91€ (approximately 1900 RMB) was provided. Consequently, the service was free. Furthermore, given the large scale of the travel time and distance matrixes, a lot of requests were needed. In fact, 478479 requests were made in order to set the tool an finally get all the results.

Moreover, although this method is much more efficient than looking one by one every distance and time, it is still time consuming given the great number of requests. Besides, with the basic billing plan, just 100000 requests per day can be obtained, hence at least 5 days are needed to properly build both matrixes.

Once the matrixes are obtained, it must be checked that they are consistent with the locations. Consequently, just zero values must be found in the diagonal and those stores with the same location. Moreover, higher values are expected to be found for those stores location far away from each other. Given the large size of the matrix, the checking step is also time-consuming.

Finally, travel time and distance matrixes are obtained and ready to be used for the implementation of the model.

# Chapter 5: Mathematical formulation

## 5.1 Introduction

In this chapter, two different mathematical formulation are presented. Both formulations would lead to find the optimal solution for the problem raised. However, there are important differences between them. The greatest difference is that a three-index formulation specifies the route that every vehicle will follow. On the other hand, a two-index formulation it does not explicitly establish the route that every vehicle will follow to deliver goods in Family Mart stores. Once both mathematical formulations are described and explained, a comparative analysis closes the section.

## 5.2 Three-index formulation

In this section, the mathematical problem to optimize is outlined. It is based on a directed graph $G = (V, A)$ composed by a set of nodes $V = \{V_0, V_1, \dots, V_m\}$ and arcs $A = \{(i, j)/\ i, j \in\ V, i \neq j\}$. It is important to note that $V_0$ stands for the depot.

### 5.2.1 Data

The data needed to model the problem described is the following:

| | |
|---|---|
| $d_i$ | Instant when the demand at node *i* needs to be satisfied, $d_i \in \mathbb{R}^+$, $\forall i \in V \setminus \{V_0\}$ |
| $p_i$ | Units of boxes to be delivered at node *i*, $p_i \in\ \mathbb{Z}$, $\forall i \in V \setminus \{V_0\}$ |
| $t_{ij}$ | Time to overcome the arc $(i, j)$, $t_{ij} \in \mathbb{R}^+$,$\forall (i, j) \in A$ |
| $K$ | Number of vehicles available, $K \in \mathbb{Z}^+$ |
| $w$ | Time windows to deliver the products, $w \in \mathbb{R}^+$ |
| $Q$ | Capacity of the vehicle, $Q \in \mathbb{Z}^+$ |
| $C$ | Cost of using one vehicle [min] |

### 5.2.2 Variables

The variables used in the model are the following:

| | | | |
|---|---|---|---|
| $z_i^k$ | Binary, $\{0,1\}$ | 0, vehicle $k$ is not assigned to node $i$<br>1, vehicle $k$ is assigned to node $i$ | $\forall i \in V \setminus \{V_0\}, \forall k \in K$ |
| $x_{ij}^k$ | Binary, $\{0,1\}$ | 0, vehicle $k$ does not use arc $(i,j)$<br>1, vehicle $k$ uses arc $(i,j)$) | $\forall (i,j) \in A, \forall k \in K$ |
| $t_i^k$ | $t_i^k \geq 0$, Float | Instant when vehicle $k$ arrives to node $i$ | $\forall i \in V \setminus \{V_0\}, \forall k \in K$ |
| $q_i^k$ | $q_i^k \geq 0$, Integer | Load of the vehicle $k$ when it leaves node $i$ | $\forall i \in V \setminus \{V_0\}, \forall k \in K$ |

### 5.2.3 Objective function

As it has previously been said, the aim of the problem is to minimize the transportation cost meant for satisfying the needs of every Family Mart Store, that is to say, deliver all the products each store demanded. The transportation cost is defined by the time needed to overcome the distance of overall routes and the amount of vehicles used, as it can be seen in equation (5.1).

$$[min] \sum_{(i,j)\in A} \sum_{k\in K} t_{ij} \cdot x_{ij}^k + \sum_{j\in V\setminus\{V_0\}} \sum_{k\in K} C \cdot x_{0j}^k \tag{5.1}$$

### 5.2.4 Restrictions

Any solution must fulfill following restrictions:

$$\sum_{k\in K} z_i^k = ,1 \forall i \in V \setminus \{V_0\} \tag{5.2}$$

$$z_1^k = 1, \forall k \in K \tag{5.3}$$

$$\sum_{\forall j\in V\setminus\{V_0\}} x_{ij}^k = z_j^k, \forall i \in V \setminus \{V_0\}, \forall k \in K \tag{5.4}$$

$$\sum_{\forall j \in V \setminus \{V_0\}} x_{ij}^k = z_i^k \,, \forall i \in V \setminus \{V_0\}, \forall k \in K \tag{5.5}$$

$$\sum_{\forall j \in V \setminus \{V_0\}} x_{j0}^k = 1, \forall k \in K \tag{5.6}$$

$$\sum_{\forall j \in V \setminus \{V_0\}} x_{0j}^k = 1 \,, \forall k \in K \tag{5.7}$$

$$\sum_{\forall i \in V \setminus \{V_0\}} p_i \cdot z_i^k \leq Q, \forall k \in K \tag{5.8}$$

$$M_1\left(1 - x_{ij}^k\right) \geq q_i^k - q_j^k + p_j \cdot z_j^k, \forall i \in V \,, \forall j \in V \setminus \{V_0\}, \forall k \in K \tag{5.9}$$

$$q_i^k \leq Q \cdot z_i^k, \forall i \in V \setminus \{V_0\} \,, \forall k \in K \tag{5.10}$$

$$q_i^k \geq 0 \cdot z_i^k, \forall i \in V \setminus \{V_0\} \,, \forall k \in K \tag{5.11}$$

$$q_0^k = 0, \forall k \in K \tag{5.12}$$

$$M_2\left(1 - x_{ij}^k\right) \geq t_i^k + t_{ij} \cdot z_j^k - t_j^k, \forall i \in V \,, \forall j \in V \setminus \{V_0\}, \forall k \in K \tag{5.13}$$

$$t_i^k \leq (d_i + w) \cdot z_i^k, \forall i \in V \setminus \{V_0\}, \forall k \in K \tag{5.14}$$

$$t_i^k \geq (d_i - w) \cdot z_i^k, \forall i \in V \setminus \{V_0\} \,, \forall k \in K \tag{5.15}$$

$$t_0^k = 0, \forall k \in K \tag{5.16}$$

$$t_i^k \geq 0, \forall i \in V \setminus \{V_0\} \,, \forall k \in K \tag{5.17}$$

### 5.2.5 Explanation of restrictions

The sets of restrictions mathematically presented mainly regard to node connection, parity and temporal and load aspects. Moreover, it is needed to highlight the specific treatment of the depot and the definition of the variables.

More precisely, the explanation of every set of restrictions is the following:

5.2 Every node, except the warehouse, must be just assigned to one vehicle or route.

5.3 Every vehicle visits the warehouse just and only once.

5.4 Every vehicle is allowed to arrive to a node (excluding the warehouse) only if the specific node has been assigned to the regarded vehicle.

5.5 Every vehicle is allowed to depart from a node (excluding the warehouse) only if the specific node has been assigned to the regarded vehicle.

5.6 Every vehicle arrives to the warehouse just and only once.

5.7 Every vehicle departs from the warehouse just and only once.

5.8 Every vehicle must have enough capacity to satisfy all the demand of the nodes assigned to its route.

5.9 It may exist load consistency between two nodes visited consecutively. If vehicle $k$ uses arc $(i, j)$, the load of the vehicle departing from $j$ is related to the load when departing from node $i$ and the amount of load supplied at node $j$. The equation becomes redundant if the arc $(i, j)$ is not used.

5.10 The load of a vehicle departing from every assigned node can never exceed the vehicle's capacity.

5.11 The load of the vehicle departing from every assigned node can never be negative

5.12 Every vehicle leaves the warehouse empty (assumption explained in Section 4.3 )

5.13 It may exist time consistency between two nodes visited consecutively. If vehicle $k$ uses arc $(i, j)$, the instant the vehicle $k$ departs from node $i$ must be related with the travel time and the instant vehicle $k$ arrives at node $j$. The equation becomes redundant if the arc $(i,j)$ is not used.

5.14 Every vehicle needs to satisfy the demand of the assigned nodes before the given time window finishes.

5.15 Every vehicle can satisfy the demand of the assigned nodes before the requested time. The earliest, the time window given.

5.16 Every vehicle departs from the warehouse at instant 0.

5.17 Non-negativity of delivery time variable

#### *5.2.5.1 Subtour elimination constraints*

Usually, in a Vehicle Routing Problem, as explained in Chapter 2: , it is necessary to add a condition regarding subtour elimination. However, when dealing with a TWVRP, the set of temporal constraints represent, at the same time, the set of restrictions for subtour elimination. This fact is caused because the instant the vehicle arrives to a node is determined. Consequently, it cannot be visited again, it is not possible to travel back in time.

## 5.3 Two-index formulation

In this section it is outlined a two-index alternative to solve the problem raised. Since the aim is to solve the same problem, its features remain the same. Consequently, the problem statement and the data set remains constant. However, given that different variables are used, the objective function and restrictions do change.

### 5.3.2 Variables

The variables used in the model are the following:

| | | | |
|---|---|---|---|
| $y_{ij}$ | Binary, $\{0,1\}$ | 0, arc $(i,j)$ is not used<br>1, arc $(i,j)$ is used | $\forall(i,j) \in A$ |
| $l_i$ | $l_i \geq 0$, float | Load of the vehicle leaving node $i$ | $\forall i \in V$ |
| $t_i$ | $t_i \geq 0$, float | Instant when the vehicle arrives to node $i$ | $\forall i \in V$ |

### 5.3.3 Objective function

As expected, the concept of the objective function remains the same: minimize the transportation cost meant for satisfying the needs of every Family Mart Store, that is to say, deliver all the products each store demanded. The transportation cost is again defined by the time needed to overcome the distance of overall routes, as it can be seen in equation (5.18).

$$[min] \sum_{(i,j)\in A} t_{ij} \cdot y_{ij} + \sum_{j\in V\setminus\{V_0\}} C \cdot y_{0j} \tag{5.18}$$

### 5.3.4 Restrictions

Any solution must fulfill following restrictions:

$$\sum_{j\in V} y_{ij} = 1, \forall i \in V \setminus \{V_0\} \tag{5.19}$$

$$\sum_{j\in V|i\neq j} y_{ji} = \sum_{j\in V|i\neq j} y_{ij}, \forall i \in V \setminus \{V_0\} \tag{5.20}$$

$$\sum_{j\in V\setminus\{V_0\}} y_{0j} \leq |K| \tag{5.21}$$

$$l_j \geq l_i + p_j - M_2(1 - y_{ij}), \forall i \in V, \forall j \in V \setminus \{V_0\} \tag{5.22}$$

$$l_j \leq l_i + p_j + M_2(1 - y_{ij}), \forall i \in V, \forall j \in V \setminus \{V_0\} \tag{5.23}$$

$$l_i \leq Q, \forall i \in V \tag{5.24}$$

$$l_0 = 0 \tag{5.25}$$

$$t_j \geq t_i + t_{ij} - M_1(1 - y_{ij}), \forall i \in V, \forall j \in V \setminus \{V_0\} \quad (5.26)$$

$$t_i \leq d_i + w, \forall i \in V \setminus \{V_0\} \quad (5.27)$$

$$t_i \geq d_i - w, \forall i \in V \setminus \{V_0\} \quad (5.28)$$

$$t_0 = 0 \quad (5.29)$$

### 5.3.5 Explanation of restrictions

Again, the sets of restrictions regard to node connection, parity and temporal and load aspects. More precisely, the explanation of every set of restrictions is the following:

5.19 Every node (except of the warehouse) is visited just and only once.

5.20 If there is an arc used to arrive to a node (except of the warehouse) there will also be an arc used to depart from it.

5.21 The amount of arcs that depart from the warehouse must be, at most, the amount of vehicles that can be used to supply all the demand.

5.22 It may exist load consistency between two nodes visited consecutively. If arc $(i, j)$ is used, the load of the vehicle departing from $j$ is related to the load when departing from node $i$ and the amount of load supplied at node $j$. The equation becomes redundant if arc $(i, j)$ is not used.

5.23 It may exist load consistency between two nodes visited consecutively. If arc $(i, j)$ is used, the load of the vehicle departing from $j$ is related to the load when departing from node $i$ and the amount of load supplied at node $j$. The equation becomes redundant if arc $(i, j)$ is not used. This second constraint is necessary, along with equation (5.22), so the variable $l_j$ is exactly the addition of $l_i$ and $p_j$ , if arc $(i, j)$ is used.

5.24 The load of any vehicle departing from any node can never exceed vehicle's capacity.

5.25 Every vehicle leaves the warehouse empty (assumption explained in Chapter 4: )

5.26 It may exist time consistency between two nodes visited consecutively. If arc $(i, j)$ is used, the instant the vehicle departs from node $i$ must be related with the travel time and the instant the vehicle arrives at node $j$. The equation becomes redundant if the edge is not used.

5.27 The demand of any node (except of the warehouse) must be satisfied before the given time window finishes.

5.28 The demand of any node (except of the warehouse) can be satisfied before the requested time. The earliest, the time window given.

5.29 Every vehicle departs from the warehouse at instant 0.

#### *5.2.5.1Subtour elimination constraints*

As commented before, it is important to highlight that usually, when working with two-index formulations, the set of restrictions regarding subtour elimination constraint is no longer needed. This fact is given by the load set of restrictions. In the case that the vehicle is collecting products, at some point, the vehicle will be full. Hence, since the demand of the warehouse is established as zero, restrictions will force the vehicle to come back to the depot. Consequently, all the routes will finish at the warehouse so no subtour will be created. In any case, as noted before, the set of temporal restrictions prevent, at the same time, the creation of subtour.

## 5.4 Comparative assessment

In this section it can be found a brief assessment of the alternatives presented.

At first glance it could seem that both formulations are quite similar since both have more or less the same number of restriction sets. Furthermore, both are based on the loads when departing from the nodes.

However, when looking at them more carefully, it can be stated that there is a feature than clearly distinguish them. As noted, three-index formulation is based on specifying the route that every vehicle follows. Consequently, every set of variables and restrictions consider variable $k$, that is to say, what defines every route. On the other hand, two-index formulation does not explicitly specify the route, so overall set of variables and restrictions is much smaller. However, everything has its counterpart and, in this case, once the solution is obtained, some data treatment is needed to define the resulting routes.

It is important to highlight that the difference is determined by the variable $k$. Consequently, as more vehicles are considered, the difference between using one or another alternative will be more noticeable.

Regarding the number of variables used, it can be seen in Table 5.1 and Table 5.2 that the order of magnitude of the number of variables in three-index formulation is $kn^2$ while in two-index formulation is just $n^2$. Consequently, a larger number of routes considered implies a greater difference between both formulations.

| **Variable set** | **Variable type** | **Number of variables** |
|---|---|---|
| $z_i^k, \forall i \in V \setminus \{V_0\}, \forall k \in K$ | Binary | $k(n-1)$ |
| $x_{ij}^k, \forall (i,j) \in A, \forall k \in K$ | Binay | $k(n^2-n)$ |
| $t_i^k, \forall i \in V \setminus \{V_0\}, \forall k \in K$ | Float | $k(n-1)$ |
| $q_i^k, \forall i \in V \setminus \{V_0\}, \forall k \in K$ | Float | $k(n-1)$ |
| | **TOTAL** | $kn^2 + 2kn - 3k \sim kn^2$ |

Table 5.1Variables of three-index formulation.

| **Variable set** | **Variable type** | **Number of variables** |
|---|---|---|
| $y_{ij}, \forall (i,j) \in A$ | Binary | $(n^2-n)$ |
| $l_i, \forall i \in V$ | Float | $n$ |
| $t_i, \forall i \in V$ | Float | $n$ |
| | **TOTAL** | $n^2 + n \sim n^2$ |

Table 5.2 Variables of two-index formulation.

Furthermore, regarding the number of restrictions to fulfil, it can be seen in Table 5.3 and Table 5.4 that the order of magnitude of the number of restrictions in three-index formulation is $2kn^2$ while in two-index formulation is just $2n^2$. Consequently, again, a larger number of routes considered implies a greater difference between the amount of restrictions used.

In Table 5.5, it can be seen a summary of the order of magnitude of the number of variables and restrictions used in every formulation.

| Restriction set | Number of restrictions |
|---|---|
| 5.2 | $n-1$ |
| 5.3 | $k$ |
| 5.4 | $k(n-1)$ |
| 5.5 | $k(n-1)$ |
| 5.6 | $k$ |
| 5.7 | $k$ |
| 5.8 | $k$ |
| 5.9 | $k(n^2-n)$ |
| 5.10 | $k(n-1)$ |
| 5.11 | $k(n-1)$ |
| 5.12 | $k$ |
| 5.13 | $k(n^2-n)$ |
| 5.14 | $k(n-1)$ |
| 5.15 | $k(n-1)$ |
| 5.16 | $k$ |
| 5.17 | $k(n-1)$ |
| **TOTAL** | $2kn^2+(3k+1)n+(1-k)\sim 2kn^2$ |

Table 5.3 Restrictions used in three-index formulation.

| Restriction set | Number of restrictions |
|---|---|
| 5.19 | $n-1$ |
| 5.20 | $n-1$ |
| 5.21 | 1 |
| 5.22 | $n^2-n$ |
| 5.23 | $n^2-n$ |
| 5.24 | $n$ |
| 5.25 | 1 |
| 5.26 | $n^2-n$ |
| 5.27 | $n-1$ |
| 5.28 | $n-1$ |
| 5.29 | 1 |
| | **TOTAL** $3n^2+2n-1\sim 3n^2$ |

Table 5.4 Restrictions used in two-index formulation.

| | **Three-index formulation** | **Two-index formulation** |
|---|---|---|
| Number of variables | $kn^2$ | $n^2$ |
| Number of restrictions | $2kn^2$ | $3n^2$ |

Table 5.5 Order of magnitude of the number of variables and restrictions used both formulations.

# Chapter 6: Heuristic formulation

## 6.1 Introduction

In this section, it is described a heuristic to solve the problem raised. One of the classic algorithms to solve a VRP problem is the one developed by Clarke and Wright, explained in Chapter 2: . Hence, the heuristic conducted is based on the Clarke and Wright. However, since different constraints are considered, it is modified to better fit the proposed problem.

## 6.2 Concept

The main concept used in the heuristic proposed is the concept of savings. When considering merging two different routes, in the case it is feasible, a saving can be generated.

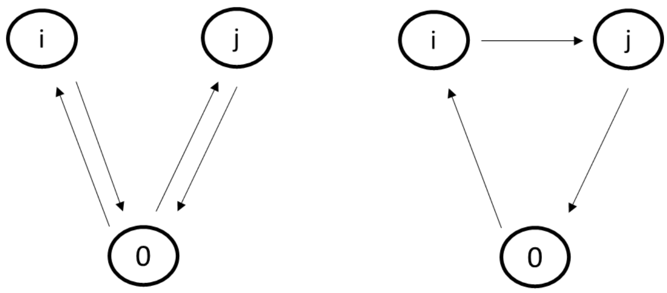


Figure 6.1 Representation of the savings when merging two routes.

Initial situation is represented by equation (6.1), final situation is represented by equation (6.2) and savings obtained is represented by equation (6.3), where $t_{ij}$ represents the travel time node *i* to *j*. In this case, the time is considered the cost associated to the arc.

$$t_{0i} + t_{i0} + t_{0j} + t_{j0} \tag{6.1}$$

$$t_{0i} + t_{ij} + t_{j0} \tag{6.2}$$

$$t_{0i} + t_{i0} + t_{0j} + t_{j0} - \left(t_{0i} + t_{ij} + t_{j0}\right) = t_{i0} + t_{0j} - t_{ij} \tag{6.3}$$

The algorithm developed starts by creating *N* routes, that is to say, a route for every node excluding the warehouse. Consequently, every route will start at the depot, visit the assigned node, and come back again to the warehouse as seen in Figure 2.2Figure 6.2.

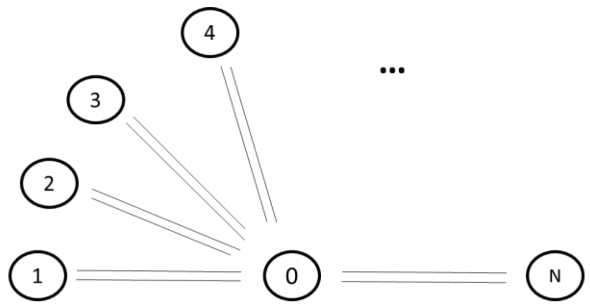


Figure 6.2 Initial phase of heuristic.

As in the algorithm developed by Clarke and Wright, the aim now is to choose a route and try to introduce more nodes to it. However, it will just occur in case it is feasible to introduce the node considering vehicle's capacity and savings.

In order to choose which route is better to start with, the algorithm described by Clark and Wright calculates all possible combinations and start with the one that generates more savings. However, in the problem raised, demands must be supplied in a specific time window. Consequently, since the time plays an important role, the first route to choose to introduce more nodes will be the one with earliest delivery time. In the case there are two nodes with the earliest demand instant, the one closer to the depot is chosen.

Once the node with the earliest delivery time is chosen, it is time to introduce more nodes to its route, so savings are generated. It is important to highlight that, due to time constraints, if it is feasible to introduce a node to the selected route, the introduced node will always be the latest to visit before coming back to the warehouse again. For instance, if the route chosen to introduce more nodes to it is the route of node 3, other nodes can be visited after visiting node 3, before coming back to the depot.

Once the route is chosen, it is time to check which nodes are feasible to introduce to the chosen route. Their feasibility will not just be given by the vehicle's capacity but also time constraints.

On one hand, it is necessary to make sure that the vehicle has enough capacity to supply the node that is desired to be introduced. On the other hand, regarding time constraints, it is necessary to consider the time window and the delivery time. If the time that the vehicle can reach the new node belongs to the accepted delivery time window, it is feasible to introduce the node. However, if the time the vehicle arrives to the new node does not belong to the time window considered, it is not feasible to introduce the node in the route, so another vehicle will be needed for satisfying its demand.

Hence, given that the set of feasible nodes is determined, it is time to compute the savings produced following equation (6.3). Once all the savings are calculated, they need to be sorted in a non-increasing order, so the node that presents more savings can be chosen. In the case that there are two feasible nodes with the same savings, the one with earlier demand instant is chosen.

Given that the node to be introduced is determined, it is added to the selected route so that the vehicle visits two nodes before going back to the warehouse.

The same procedure must be now applied in order to introduce more nodes to the route. However, in this new iteration, just the nodes that has not been previously selected must be checked again to evaluate their feasibility. In this way, the nodes that will fulfill the requirements will be introduced in the route until it is not feasible to introduce any more nodes.

At this moment, it is time to choose another node that has not previously been introduced to any route to assess the possibility to introduce more nodes to its route. Consequently, the process described starts again.

Following an iterative procedure, the same reasoning will be applied until all feasible routes are studied and all nodes are considered in the different routes. At this point, a solution for the raised problem will be obtained. However, as it has been said, it will probably not be the optimal solution and, depending on the set of data, the solution can differ more or less from the optimal one.

Before moving to the following section, it is important to note that, as it happens with

Clark and Wright algorithm, it assumes that there is no restriction of the number of vehicles used. In the problem raised, there is a limitation of vehicles.

Consequently, in the case the solution uses more vehicles than the available ones, the algorithm can be modified so negative savings are accepted. If this is the case, when merging two routes, instead of implying a saving, it may generate a cost. However, this cost is necessary to overcome the restriction regarding the number of vehicles used.

Finally, it is also important to highlight that, as previously noted, the solution obtained is not the optimal one. Hence, there are other heuristics than can be applied in order to improve the result, so that the solution is closer to the optimal one. However, since time plays an important role in the stated problem, most of the best known improving algorithms cannot be applied.

## 6.3 Data

In order to understand the formulation, it is first necessary to indicate the data used in it. Since the aim is to solve the same problem, the data described in Section 455.2.1 is the same data used for the heuristic.

## 6.4 Formulation

In this section it can be found the math description of the process outlined.

It is important to highlight that the algorithm itself is defined as an iterative process until a solution for the problem is found.

<u>Step 0:</u> Initial phase

Create N routes, a route for every node $i$, $i \in V \backslash V\{0\}$ and define the set of nodes $M$, that represent the set of nodes that are already visited and also the set of nodes $T$, that represent the set of nodes that need to be visited. Hence, $V = M + T + \{0\}$.

Initially sets $M$ and $T$ are represented by (6.4) and (6.5). Moreover, a counter $j$ is fixed to $j = 1$.

$$M = \{\emptyset\} \tag{6.4}$$

$$T = V - M - \{0\} \tag{6.5}$$

Step 1: Route selection

If set $T$ is empty, that is to say, if $T = \{\emptyset\}$, it is the end of the algorithm. Otherwise, if $T \neq \{\emptyset\}$, it must be selected $i_1 \in T$ such that it fulfills equation (6.6). Hence, sets $M$ and $T$ must be updated following equations (6.7) and (6.8). Furthermore, the instant and the load of the vehicle when arriving to node $i_1$ also needs to be updated following equations (6.9) and (6.10). In case there are two nodes with the earliest instant demand, equations (6.11) must be followed.

$$d_{i_1} = \min \{d_r \mid r \in T \} \tag{6.6}$$

$$M = M + \{i_1\} \tag{6.7}$$

$$T = T + \{i_1\} \tag{6.8}$$

$$t_{i_1} = max \{ d_{i_1} - D, \, t_{0i_1} \} \tag{6.9}$$

$$l_{i_1} = p_{i_1} \tag{6.10}$$

$$d_{i_1} = \min \{t_{0k} \mid k \in (\min d_r ) \} \tag{6.11}$$

Step 2: Introduction of nodes in the selected route

If it exists a node $i_{j+1} \in T$ that fulfills equation (6.12), sets $M$ and $T$ must be updated following equations (6.13) and (6.14). Furthermore, the instant and the load of the vehicle when arriving to node $i_{j+1}$ also needs to be updated following equations (6.15) and (6.16). After introducing node $i_{j+1}$, if set $T$ is empty, that is to say, if $T = \{\emptyset\}$, it is the end of the algorithm. Otherwise, if $T \neq \{\emptyset\}$, the counter $j$ must be $j = j + 1$ so that another $i_{j+1} \in T$

must be found.

$$S_{i_j i_{j+1}} = \max \left\{ S_{i_j k} = t_{i_j 0} + t_{0k} - t_{i_j k} \mid S_{i_j k} \geq 0,\ l_{i_j} + p_k \leq Q, \right. \tag{6.12}$$

$$\left. t_{i_j} + t_{i_j k} \leq d_k + D,\ t_{i_j} + t_{i_j k} \leq d_k - D, k \in T \right\}$$

$$M = M + \{i_{j+1}\} \tag{6.13}$$

$$T = T + \{i_{j+1}\} \tag{6.14}$$

$$t_{i_{j+1}} = \max \{ d_{i_{j+1}} - D, t_{i_j} + t_{i_j i_{j+1}} \} \tag{6.15}$$

$$l_{i_{j+1}} = l_{i_j} + p_{i_{j+1}} \tag{6.16}$$

$$S_{i_j i_{j+1}} = \min \left\{ d_k \mid k \in (\max S_{i_j k}) \right\} \tag{6.17}$$

If it does not exist a node $i_{j+1} \in T$ that fulfills equation (6.11), step 1 must be started again.

# Chapter 7: Implementation

## 7.1 Introduction

So far, two models to find the optimal solution and an heuristic have been developed in order to find a solution for the problem raised. However, it is now time to implement the options described. Hence, in the first part of the chapter, the two-index and three-index formulations developed in Chapter 5: are implemented in a optimizer solver so-called CPLEX. Moreover, the instances solved are described. In the second part of the chapter, the heuristic formulation developed in Chapter 6: is implemented in Matlab, a numerical computing software. Again, the instances implemented are outlined.

## 7.2 Optimal solution: CPLEX

As explained, CPLEX Optimizer is the solver used to implement the formulations. Hence, a brief explanation of the solver and its features can be found. Thereafter, the model and data files for every formulation outlined in Chapter 5: are shown and explained.

### 7.2.1 CPLEX Optimizer

CPLEX is an optimization software package commercialized by IBM ILOG. CPLEX can solve linear programming problems, mixed integer programming problems, quadratic programs, mixed integer quadratic programs, quadratic constraint programs and mixed integer quadratic constrained programs. Moreover, to solve other problem, the instance MINLP can also be used. [23]

CPLEX optimizer last version, 12.7.1, was launched in 2017 and its computational performance is the result of a combination of different types of improvements in LP solvers, cutting planes, heuristics and parallelization.

The main idea used to solve Mixed integer linear programming problems (MILP) is the branch and cut algorithm, that is based on the brunch and bound algorithm explained in Section 2.8.2 Therefore, it provides a solution that has been found by solving a sequence of linear relaxations to provide bounds. However, there is a pre-processing step and addition of cutting planes in order to be more suitable for large scale problems. The aim of the pre-processing is to reduce the size of the problem and improve its formulation. Hence, a new model is defined, a tighter one that does not increase the size of the problem and that is independent of the relaxation solution.

In order to solve any problem in CPLEX two different files are needed. On one hand, a file .mod is needed to develop the model. One the other hand, another file .dat is needed so that the model knows what data must be considered as an input.

Moreover, it is interesting to note that CPLEX has been used by means of Optimization Programming Language (OPL). It is a modeling language for combinatorial optimization, designed to substantially simplify optimization problems.[22] It is very convenient to use because it is very similar to the mathematical expressions. However, if more complex problems need to be described, some other programming languages such C++ or Java can also be used in CPLEX.

### 7.2.2 Three-index formulation

In order to implement the three-index formulation, files .mod and .dat are needed. The model file can be seen in Figure 7.1, Figure 7.2 and Figure 7.3.

In the first part of the model, in Figure 7.1, the network is outlined. Moreover, the data is called from the data file so the network and its features its completely defined. Furthermore, it is necessary to define the variables and the objective function. Finally, the restrictions of Section 2.7.1 are specified in Figure 7.2 and Figure 7.3. It is important to note that, as the output, the solver gives back the values of the all variables.

```
//Definition of the network
   int n_cities  = ...;
   int n_vehicles = ...;
   range Cities  = 1..n_cities;
   range Shops  = 2..n_cities;
   range Vehicles = 1..n_vehicles;
   tuple arco { int ini; int fin; }
   {arco} Arches={ <ini, fin> | ini, fin in Cities: ini!=fin};

//Data provided
   int Q= ...;
   int D= ...;
   int C=...;
   int Demand[Cities]    = ...;
   int TT[Arches]          = ...;
   int Inst_Demand[Cities] = ...;

//Variables
   dvar boolean X[Arches, Vehicles];
   dvar boolean Z[Cities, Vehicles];
   dvar float   U[Cities, Vehicles];
   dvar float   t[Cities,Vehicles];

//Objective function
   minimize (sum(a in Arches, v in Vehicles) TT[a] * X[a,v] + sum(a in Arches: a.ini==1, v in Vehicles) C*X[a,v]);
```

Figure 7.1 Model file of three-index formulation. Part 1.

```
//Restrictions
   subject to{

      //Constraint 5.2:
      forall(c in Cities: c!=1)   sum(v in Vehicles) Z[c,v] == 1;

      //Constraint 5.3:
      forall(v in Vehicles)       Z[1,v]==1;

      //Constraint 5.4:
      forall (c in Shops, v in Vehicles)  sum(a in Arches: a.fin==c) X[a,v] == Z[c,v];

      //Constraint 5.5:
      forall (c in Shops, v in Vehicles)  sum(a in Arches: a.ini==c) X[a,v] == Z[c,v];

      //Constraint 5.6:
      forall (v in Vehicles)      sum(a in Arches : a.fin==1) X[a,v] == 1;

      //Constraint 5.7:
      forall (v in Vehicles)      sum(a in Arches : a.ini==1) X[a,v] == 1;

      //Constraint 5.8:
      forall (v in Vehicles)      sum(c in Shops) Demand[c] * Z[c,v] <= Q;

      //Constraint 5.9:
      forall(c in Cities, d in Shops : c!=d, v in Vehicles)
          U[c,v]-U[d,v]+Demand[d]*Z[d,v]<= 1000*(1-X[<c,d>,v]);

      //Constraint 5.10:
      forall (c in Shops, v in Vehicles)  U[c,v] <= Q*Z[c,v];

      //Constraint 5.11:
      forall (c in Shops, v in Vehicles)  U[c,v] >= 0*Z[c,v];
```

Figure 7.2 Model file of three-index formulation. Part 2.

```
    //Constraint 5.12:
    forall (k in Vehicles)            U[1,k] == 0;

    //Constraint 5.13:
    forall(c in Cities, d in Shops : c!=d, v in Vehicles)
        t[c,v]-t[d,v] + TT[<c,d>]*Z[d,v] <= 1000*(1-X[<c,d>,v]);

    //Constraint 5.14:
    forall (c in Cities, v in Vehicles) t[c,v] <= (Inst_Demand[c] + D) * Z[c,v];

    //Constraint 5.15:
    forall (c in Cities, v in Vehicles) t[c,v] >= (Inst_Demand[c] - D) * Z[c,v];

    //Constraint 5.16:
    forall (k in Vehicles)            t[1,k] == 0;

    //Constraint 5.17:
    forall (i in Shops, k in Vehicles)  t[i,k] >= 0;
}
```

Figure 7.3 Model file of three-index formulation. Part 3.

The model file calls another data file in order to input the data needed for the model. Since the data set for the problem is very large, a small example of another instance of the data set can be seen in Figure 7.4.

```
n_cities = 7;
n_vehicles = 2;

Q = 9;
D=5;
C=5;


Demand = [0 2 3 5 2 1 1];
Inst_Demand = [0 2 5 4 15 18 20];

TT =[     1  2  3  4  5  6
      1      2  3  4  4  4
      2  4      3  10 4  4
      3  4  5      5  4  4
      4  4  5  6      3  3
      5  4  4  4  10     2
      6  4  3  4  12 5    ];
```

Figure 7.4 Example of a data file for three-index formulation.

### 7.2.3 Two-index formulation

Again, in order to implement two-index formulation, files .mod and .dat are needed. The model file can be seen in Figure 7.5, Figure 7.6 and Figure 7.7.

```
execute PARAMS {
  cplex.tilim = 18000;
}

//Definition of the network
    int n_cities  = ...;
    range Cities  = 1..n_cities;
    range Shops  = 2..n_cities;
    int Q= ...;
    int D= ...;
    int n_vehicles = ...;
    int C= ...;

//Data provided

    int Demand[Cities]    = ...;
    float TT[Cities][Cities]= ...;
    float Inst_Demand[Cities] = ...;

//Variables
    dvar boolean X[Cities, Cities];
    dvar float   U[Cities];
    dvar float   t[Cities];

//Objective function
    minimize (sum(i in Cities,j in Cities)TT[i,j]*X[i,j] + sum(j in Shops) C*X[1,j]);
```

Figure 7.5 Model file of two-index formulation. Part 1.

```
//Restrictions
subject to {
    //Constraint 0:
    forall (i in Cities) X[i,i]==0;

    //Constraint 5.19:
    forall (i in Shops) sum (j in Cities) X[i,j] ==1;

    //Constraint 5.20:
    forall (i in Shops) sum (j in Cities) X[j,i] == sum(j in Cities)X[i,j];

    //Constraint 5.21:
    sum (j in Shops) X[1,j]<=n_vehicles;

    //Constraint 5.22:
    forall(i in Cities, j in Shops) U [i] + Demand[j] - 1000*(1-X[i,j])<= U[j];

    //Constraint 5.23:
    forall(i in Cities, j in Shops) U [i] + Demand[j] + 1000*(1-X[i,j])>= U[j];

    //Constraint 5.24:
    forall (i in Cities) U[i] <=Q;

    //Constraint 5.25:
    U[1] == 0;
```

Figure 7.6 Model file of two-index formulation. Part 2.

```
//Constraint 5.26:
forall (i in Cities, j in Shops) t[j]>=t[i]+TT[i,j]-100*(1-X[i,j]);

//Constraint 5.27:
forall (i in Shops) t[i]<= D + Inst_Demand[i];

//Constraint 5.28:
forall (i in Shops) t[i]>= - D + Inst_Demand[i];

//Constraint 5.29:
t[1] == 0;
}
```

Figure 7.7 Model file of two-index formulation. Part 3.

The structure followed is exactly the same one described in the three-index formulatoin. In the first part of the model, the network is outlined. Moreover, the data is called from the data file so the network and its features its completely defined. Furthermore, it is necessary to define the variables and the objective function. Finally, the restrictions of Section 5.3.4 are specified.

As it can be seen in Figure 7.6 and Figure 7.7, there is a difference regarding the mathematical formulation presented in Section 5.3.4 .

In the restrictions set, there is a set of constraints so-called Constraint 0. The set of constraints is necessary given the data used. The model is created so that all the arcs between nodes are considered. Hence, the arc from node *i* to node *i* is also created. In the data file, this arc is set to have a zero cost, so the model could try to use it in the solution. To avoid this fact, a new set of constraints is outlined. The set imposes that the arcs with the same origin and destination cannot be used in the solution.

In Figure 7.8 it can be seen an example of a data file for two-index formulation. Again, the size of the real data set is so large so a small example is shown.

```
n_cities = 7;
n_vehicles = 2;

Q = 9;
D=5;
C=2;

Demand = [0 2 3 5 2 1 1];
Inst_Demand = [0 2 5 4 15 18 20];

TT =[[0  1  2  3  4  5  6]
     [1  0  2  3  4  4  4]
     [2  4  0  3  10 4  4]
     [3  4  5  0  5  4  4]
     [4  4  5  6  0  3  3]
     [5  4  4  4  10 0  2]
     [6  4  3  4  12 5  0]];
```

Figure 7.8 Example of a data file for two-index formulation.

### 7.2.4 Instance solved

One of the aims of the project is to find the optimal routes to deliver the refrigerated products to all Family Mart. Hence, the actual instance that needs to be solved is for the whole set of data, that is to say, for the 450 Family Mart stores.

However, as it will be further explained in Section 2.5 , considering that is a NP hard problem, the instance to solve is too large. Hence, it is necessary to divide the problem in smaller instances so an optimal solution can be found for every part of the problem.

The fact of dividing the whole problem has its advantages and disadvantages. On one hand, when the optimal solution for every part is obtained, an overall good solution is found for the whole problem. However, it cannot be said that is the optimal one since the optimal one could merge together in the same route nodes from different parts. Consequently, the division considered, has a great effect on the result. On the other hand, this is the only way the models formulated can be applied and can give a solution in a reasonable amount of time.

In order to divide the problem into smaller instances, two variables have been considered: the number of nodes of every instance and their location.

On one hand, the number of nodes of every instance cannot be higher than 100 since, otherwise, the computational time needed to solve the instance is already very high. Moreover, it is better that the number of nodes of every instance is more or less similar. Hence, around 70-90 nodes per instance are considered.

On the other hand, the location of the nodes selected is essential, since you are forcing routes to pass by them. Hence, nodes in the same area must be considered since the optimal solution minimizes the distance travelled, so nodes close to each other are merged into the same route.

Finally, the problem has been divided into 6 smaller problems as seen in Figure 7.9.

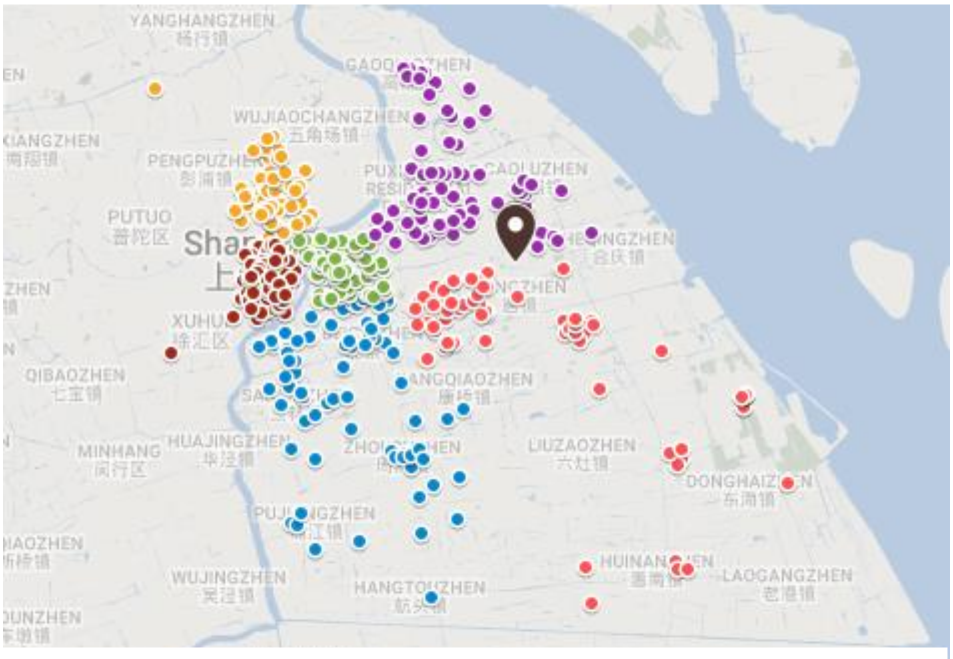


Figure 7.9 Problem division into 6 groups.

As it can be seen in Figure 7.9, geographic features really determine the problem division. The number of nodes considered in every instance can be seen in Table 7.1.

| | **Group 1** | **Group 2** | **Group 3** | **Group 4** | **Group 5** | **Group 6** |
|---|---|---|---|---|---|---|
| **Associated color** | Yellow | Brown | Green | Blue | Red | Purple |
| **Number of nodes** | 61 | 92 | 81 | 74 | 72 | 70 |

Table 7.1 Problem division into 6 different groups.

The data needed for the model is the one outlined in Section 5.2.1 First of all, the amount of nodes considered needs to be specified.

Since every part of the problem has been solved separately, the number of stores considered in every instance is the one represented in Table 7.1. However, the warehouse needs to be added.

Moreover, no restrictions in the amount of vehicle have been implemented. Hence, for every instance solved, that is to say, for every group, 15 vehicles have been considered. Regarding the capacity of the vehicle, as explained in Section 4.3 200 plastic boxes are considered for every truck.

Regarding demand, a uniform demand is considered to be 12 boxes/store. The value comes from the data that Hitachi provided since it is assumed that trucks leave more or less full and every truck visits 17 stores before coming back to the warehouse. Hence, the resulting number can be rounded to 12 boxes per store. However, in this instance, a non-uniform demand is considered, an approximation of a normal distribution is applied. A normal distribution is a continuous probability distribution. Hence, considering that the units demanded are full boxes, a simple normal distribution cannot be applied since it could result in supplying, for instance, 5.7 boxes. In order to avoid that, a normal distribution is first applied and, afterwards, the values have been rounded. The result of it is what is has been called an approximation of a normal distribution. For that, it has been considered a normal distribution $N\sim(12,3)$ and afterwards it has been rounded.

Regarding the instant demand, a normal distribution has also been considered. In this case, $N\sim(40,8)$. Hence, from the warehouse, vehicles have enough time to go to almost all stores, so no restriction is applied.

Moreover, regarding the objective function, a parameter $C$ is applied in order to specify a cost for every vehicle used. In this case, a value of 100 has been considered. In addition, time window does not have an effect since parameter $D$ has been considered 40. Hence, the products can be supplied almost anytime.

Finally, the model also needs the travel time distance obtained in Section 4.5.2.

## 7.3 Heuristic: MATLAB

In order to implement the formulation described in Chapter 6: , a numerical computing software needs to be used. In this case, it has been chosen to use Matlab. Matlab allows the implementation of algorithms, among other applications such matrix manipulation and data analysis.

For a better understanding of the code used, Figure 7.10 describes in a schematic way the formulation and loops outlined.

As it can be seen, there are three main phases: initial phase, route selection and merging routes.

The initial phase is just represented by step 0, which inputs the data and creates the vectors needed in the algorithm.

The route selection, the second phase, is represented by steps 1, 2 and 3. Step 1 selects the node chosen to start with, that is to say, the node with lower instant demand. Step 2 specifies that, if there are more than two nodes with the same instant demand, it selects the one closer to the warehouse. Once the node is selected, step 3 updates the data needed.

The third phase, merging routes, is represented by steps 4, 5, 6 and 7. Step 4 verifies whether there are nodes that fulfill equation (6.12). If so, step 5 selects the one that presents more savings. Otherwise, another route must be chosen, so route selection phase starts again. In case step 5 takes place, the node that present most savings must be chosen. However, it is possible that more than one node have the same savings. Then, step 6 verifies that the node taken is the one with lowest instant demand. Finally, step 8 updates the data. Since it is an iterative process, afterwards, step 4 must be taken again.

The process finishes when there are no more nodes that can be taken since they have been all considered before, consequently, it finishes when vector $T$ is empty.

The Matlab code of Figure 7.11 and Figure 7.12 represents the process just described. Moreover, it is organized in the same steps outlined to better understand its performance.

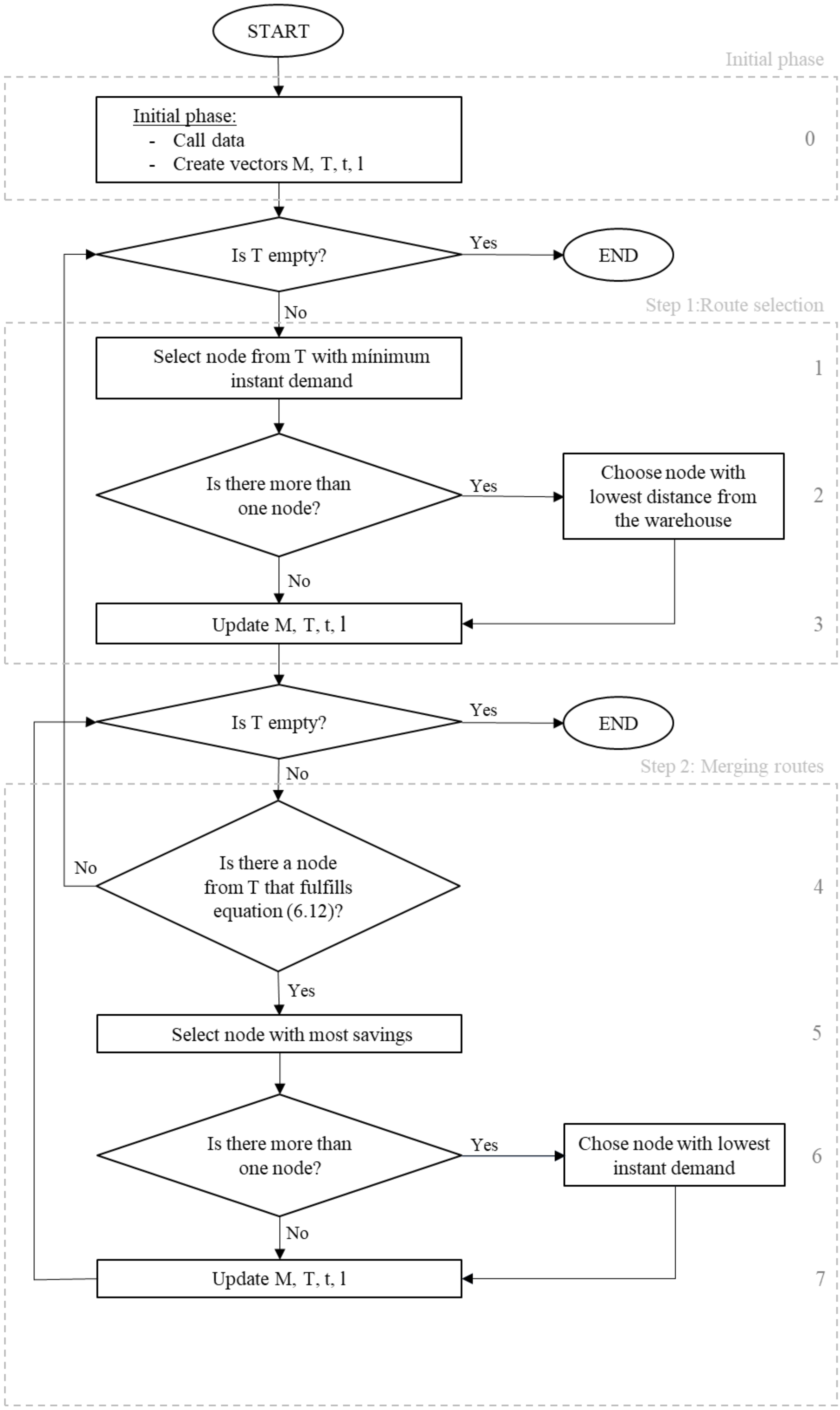


Figure 7.10 Scheme of heuristics implementation.

```
clear
clc
close all
%%Step 0: Initial phase
    %Data
        %Amount of shops (warehouse excluded)
            n_cities = 450;
        %Travel time matrix (warehouse excluded)
            TT=xlsread('C:\Users\TOT.xlsx','1','D7:QK456');
        %Travel time warehouse - node i
            TOI=xlsread('C:\Users\TOT.xlsx','1','D6:QK6');
        %Travel time node i - warehouse
            TIO=xlsread('C:\Users\TOT.xlsx','1','C7:C456');
        %Stores Demand
            Demand = xlsread('C:\Users\\TOT.xlsx','1','D2:QK2');
        %Stores Demand instant
            Inst_Demand = xlsread('C:\Users\TOT.xlsx','1','D3:QK3');
        %Vehicle's capacity (units: blue plastic box)
            Q = 200;
        %Time window accepted (+-D)
            D =20;
        %Available trucks
            N_trucks = 450;

    %Vector creation
        %Vector of nodes already visited
            M=[];
        %Vector of nodes to be visited
            T=1:n_cities;
        %Arriving time at every node
            t=zeros(1,n_cities);
        %Load of the vehicle when leaving node
            l=zeros(1,n_cities);

Z=[];
%%Route selection
   while isempty(T)== 0
        %Step 1: Select node from T with minimum instant demand
            c=min(Inst_Demand(T(1,:)));
            b=find(Inst_Demand(T(1,:))==c);
        %Step 2: Is there more than one node? Select node closest to the WH
            if size(b,2)>1
                TTi=zeros(1,size(b,2));
                for ii=1:size(b,2)
                    TTi(ii)=TT(1,T(b(ii)));
                end
                b=find(TTi==min(TTi));
            end
        %Step 3: Update M, T, t, l
            b=T(b(1));
            M = [M b];
            T = T(T~=b);
            t(b)= max((Inst_Demand(b)-D),TOI(b));
            l(b)= Demand(b);
            T1=1;
```

Figure 7.11 Implementation of heuristic in Matlab. Part 1.

```
%%Merging routes
 while isempty(T)== 0 && T1==1
 S= -1*ones(1,n_cities);
       i=b;
       ti=0;

       %Step 4: Is there a node from T that fulfills equation (6.12)?
           for j=T(1,:)
               if  l(i)+ Demand(j)<= Q && (t(i)+ TT(i,j))<=(Inst_Demand(j)+ D) && t(i)↙
+ TT(i,j)>=(Inst_Demand(j)- D)
                   Saving = TIO(i)+ TOI(j)- TT(i,j);
                   if Saving>=0 && size(Z,2)<= N_trucks
                   S(j)=Saving;
                   else
                   ti=ti+1;
                   end
               else
                  ti=ti+1;
               end
           end
       %Step 5: Select node with most savings
           if ti<size(T,2)
                    j=find(S==max(S));
                    if size(j,2)>1
                       c=min(Inst_Demand(j));
                       jj=[];
       %Step 6: Is there more than one node? Select node lowest inst demand
                       for jji=1:size(j,2)
                           if Inst_Demand(j(jji))==c
                               jj=[jj,j];
                           end
                       end
                       j=jj(1);
                    end
       %Step 7: Update M, T, t, l
                     M = [M j];
                     T = T(T~=j);
                     t(j)= max((Inst_Demand(j)-D),t(i)+ TT(i,j));
                     l(j)= l(i)+Demand(j);
                     b=j;
       else
        Z=[Z i];
        T = T(T~=i);
        T1=0;
       end
 end

     end

   clear c Saving S ti T1 i j ii jj TTi b jji k
```

Figure 7.12 Implementation of heuristic in Matlab. Part 2.

### 7.3.1 Instances solved

In contrast to the optimal solution, the heuristic method provides a non-optimal solution with a very short computational time. Furthermore, the number of nodes considered in the instance solved does not affect much in the computational time. Consequently, when applying the heuristic method, the problem has not been divided into parts but the whole problem has been considered.

Given the large computational time that takes to get a solution using methods described in 45Chapter 5: no study of the demand time restrictions affect could be done. Hence, since the implementation of heuristics is much faster, in order to address how do demand and time restrictions affect, different instances have been solved.

A summary of the features of every instance can be seen in Table 7.2 and Table 7.3. It is important to note that, for the 8 different instances, no constraints in the number of vehicles used are applied.

| | **Instance 1** | **Instance 2** | **Instance 3** | **Instance 4** |
|---|---|---|---|---|
| **Demand** | Uniform | Uniform | 'Normal distribution' | 'Normal distribution' |
| **Instant Demand** | Uniform | Uniform | Uniform | Uniform |
| **Time window** | Full time | 30 minutes | Full time | 30 minutes |
| **Vehicles used** | No constraint | No constraint | No constraint | No constraint |

Table 7.2 Instances solved applying heuristics. Part 1.

| | **Instance 5** | **Instance 6** | **Instance 7** | **Instance 8** |
|---|---|---|---|---|
| **Demand** | Uniform | Uniform | 'Normal distribution' | 'Normal distribution' |
| **Instant Demand** | Normal distribution | Normal distribution | Normal distribution | Normal distribution |
| **Time window** | Full time | 30 minutes | Full time | 30 minutes |
| **Vehicles used** | No constraint | No constraint | No constraint | No constraint |

Table 7.3 Instances solved applying heuristics. Part 2.

Regarding demand, a uniform demand is considered to be 12 boxes/store. Again, when a non-uniform demand is considered, an approximation of a normal distribution is applied $N \sim (12, 3)$ and afterwards it has been rounded.

Regarding the instant demand, a uniform instant at 40 minutes has been considered. Hence, from the warehouse, the vehicles have enough time to go to almost all stores, so no restriction is applied. Thereafter, a normal distribution $N \sim (40, 8)$ has been implemented.

Furthermore, in half of the instances time window does not have an effect since the products can be supplied anytime. In the other half of the instances, there is a fixed time window of 30 minutes to supply products.

Since all nodes have been considered, the number of stores is determined as 451, 450 stores and the warehouse. In order to supply so many stores, no restriction in the number of vehicles is applied. Again, the capacity of the vehicles is considered to be 200 boxes per truck.

Finally, the model also needs the travel time distance obtained in Section 4.5.2.

It is important to note that in the heuristic presented there is no way to impose, during the process, that every vehicle has a cost. Hence, parameter $C$ does not have any effect in the formulation.

The results obtained for the 8 instances can be seen in 0. However, given the results obtained, some more instances are studied as seen in Table 7.4.

| | **Instance 2'** | **Instance 4'** | **Instance 6'** | **Instance 8'** |
|---|---|---|---|---|
| **Demand** | Uniform | 'Normal distribution' | Uniform | 'Normal distribution' |
| **Instant Demand** | Uniform | Uniform | Normal distribution | Normal distribution |
| **Time window** | 40 minutes | 40 minutes | 40 minutes | 40 minutes |
| **Vehicles used** | No constraint | No constraint | No constraint | No constraint |

Table 7.4 Instances solved applying heuristics. Part 3.

# Chapter 8: Results

## 8.1 Introduction

In this Chapter, the results of the implementation of mathematical formulations and heuristics are presented. Hence, the chapter begins with the results obtained by implementing the three-index and two-index formulations. Later on, the results obtained from the implementation of the heuristic in Matlab are described. The chapter finishes with some insights about the results comparison.

## 8.2 Optimal solution: CPLEX

In this section, it is first described the results obtained from the implementation of the three-index formulation. Afterwards, the results from the two-index formulations are also submitted.

As explained in Section 7.2 the whole problem is too large to implement it. Hence, the problem has been divided following Table 7.1. Consequently, although an optimal solution will not probably be found, the results obtained will be quite near the optimal.

In order to build a solution for the whole problem, the set of subproblems must be solved, that is to say, every group of Table 7.1 must be solved as an independent problem.

### 8.2.1 Three-index formulation

When implementing the three-index formulation to solve the 6 subproblems, after CPLEX running for few hours, the program presents an error and no solution is obtained. The error is caused by the large number of variables used, since the optimizer does not have enough memory to store variables from the different iterations needed to obtain a solution. Hence, it can be stated that although theoretically it is a good model, it can be applied to solve small size problems. However, when dealing with problems of large scale, the model developed is not useful anymore.

### 8.2.2 Two-index formulation

As explained, CPLEX is used in order to obtain a solution for the 6 subproblems.

The first time a subproblem was solved was from the Group 1. In the first try, no restriction of computational time dedicated to solving the problem was stablished. Hence, the solver run for more than 48h without obtaining the optimal solution. However, the solution obtained after running the algorithm for around 5 hours did not change a lot from the one obtained after 48 hours. Hence, it was decided to impose a computational time of 5 hours and consider the best solution obtained so far. Moreover, if more than 5 hours it is needed to obtain a good solution, it cannot be stated that it is a good method, since it takes long time to get any results.

It is important to remind before showing the results, that the instance solved presents the features shown in Table 8.1

| | |
|---|---|
| **Instant demand** | $N\sim(40,8)$ |
| **Demand** | $N\sim(12,3)$ |
| **Time window** | 80 [min] (no effect) |
| **Vehicle capacity** | 200 [boxes] |
| **Fixed price for using one vehicle** | 100 [min] |
| **Number of vehicles** | No restriction |

Table 8.1 Data used for the exact method.

A summary of the results obtained for every subproblem, that is to say, for every group of Table 8.2 can be seen as follows.

| | Group 1 (Yellow) | Group 2 (Brown) | Group 3 (Green) | Group 4 (Blue) | Group 5 (Red) | Group 6 (Purple) |
|---|---|---|---|---|---|---|
| **Number of routes** | 5 | 7 | 5 | 7 | 5 | 6 |
| **Number of stores** | 61 | 92 | 81 | 74 | 72 | 70 |
| **Average number of stores per vehicle** | 12 | 13 | 16 | 11 | 14 | 12 |
| **Average load per vehicle** | 148 | 158 | 195 | 128 | 145 | 169 |
| **Travel time cost** | 485.38 | 687.4 | 504.58 | 736.34 | 606.15 | 501.26 |
| **Fleet cost** | 500 | 700 | 500 | 700 | 600 | 500 |
| **Total cost** | 985.38 | 1387.4 | 1004.58 | 1436.34 | 1206.15 | 1001.26 |

Table 8.2 Results of every subproblem of the exact method.

Before considering the addition of all subproblems to obtain a solution for the problem raised, it is interesting to analyze the results obtained so far.

On one hand, the cheapest subproblem is the one regarding group 1 since it has the lowest number of stores to visit and also, they are located very close to each other. Hence, travel times from shop to shop are low.

On the other hand, the most expensive subproblem is Group 4. This fact is given the low density between stores, compared with other groups, although the number of stores to visit is not that high. It is interesting to note that Group 5 seems to be more spread but there are several stores located in the same point, so travel time are very low. However, this fact cannot properly be observed in Figure 7.9 since points overlap.

Moreover, it is also interesting to comment the subproblem regarding Group 2. Although it is the subproblem with the largest number of stores to visit, since they are located very close to each other, travel time cost is low. What makes the result more expensive is the fact that seven trucks are needed since a lot of stores must be visited.

Furthermore, Group 3 presents low cost since, although quite few stores must be visited, the density of stores is very high.

Finally, it is interesting to compare Groups 4, 5 and 6 since they have approximately the same number of stores to visit but the final price is very different. This fact is given by mainly two factors. The first one is that stores from Group 6 are much closer to each other, so travel times are much lower. The second factor is given by the fact that, as explained, some of the stores from Group 5 overlap each other, reducing travel time.

Once a brief comparison of the subproblems is done, it is time to finally calculate overall solution, that is to say, add all subproblems into the initial problem raised. The final results obtained can be seen in Table 8.3.

| | |
|---|---|
| **Number of routes** | 35 |
| **Average number of stores per route** | 13 |
| **Average load per vehicle** | 155.09 |
| **Travel time cost** | 3521.11 |
| **Fleet cost** | 3500 |
| **Total cost** | 7021.11 |

Table 8.3 Results obtained from the exact method.

Hence, the final result obtained in order to implement an instance such the one described in Table A results in a total travel time cost of 3521 minutes and a vehicle cost of 3500 minutes. Hence, a total cost of 7021 minutes. Moreover, considering no restriction in the number of vehicles used, a fleet of 35 would result necessary to supply the demand of 450. Finally, the average load per truck would be 155.09, so 77.5% full.

Before moving to the results obtained by means of the heuristic method it is important to highlight that the result obtained is not the optimal one due to the subdivision of problems and the fixed computational time.

Moreover, a detailed solution of the routes of every subproblem can be found in the appendix.

## 8.3 Heuristic: MATLAB

In this section, it is first described the results obtained from the implementation of the heuristic formulation in Matlab program. Hence, an analysis of the different instances solved is outlined so the impact of the time windows, the demand and instant demand are addressed.

A summary of the results obtained for every instance solved can be seen as follows.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Number of routes** | 36 | 68 | 31 | 57 | 35 | 68 | 30 | 57 |
| **Average number of stores per vehicle** | 12.50 | 6.62 | 14.52 | 7.89 | 12.86 | 6.62 | 30.00 | 7.89 |
| **Average load per vehicle** | 150.00 | 79.41 | 174.19 | 94.74 | 153.77 | 79.15 | 179.40 | 94.42 |
| **Travel time cost** | 99.03 | 80.26 | 111.27 | 84.35 | 99.74 | 80.26 | 113.94 | 84.35 |

Table 8.4 Results of the instances 1-8 solved using the heuristic method

As it has been said, there are three aspects that need to be analyzed, the impact of the demand, the instant demand and the time window.

The first feature to analyze is the effect of a uniform or non-uniform demand. In order to do so, instances pair 1-5, 3-7, 2-6, and 4-8 are addressed. Each pair presents the same features except of the demand, as it can be seen in Table 7.2 and Table 7.3.

When comparing instances 1-5 and 3-7, it can be seen that, if there is no time restriction, overall cost hardly changes when a non-uniform demand is considered. In this case, a reduction of 2.1% and 0.9% is obtained respectively. However, it is important to stress out that the results obviously depend on the probabilistic distribution implemented. Hence, it is expected that the results may differ more when a normal distribution with higher standard deviation is considered.

When comparing instances pairs 2-6 and 4-8, the first aspect that must be noted is that in both pairs, there are time restrictions so stores must be supplied between a specific period of time. Instances 2 and 6 present exactly the same results, with the same routes. The same happen with instances 4 and 8.The only aspect that changes is the average load of the vehicles, since the demand is different. Hence, based on the results, it can be stated that when there are time constraints the effect of a non-uniform demand is not noticeable. Again, this statement is just applicable given the probabilistic distribution implemented.

The second feature to analyze is the effect of a uniform or non-uniform instant demand. In order to do so, instances pair 1-3, 2-4, 5-7, and 6-8 are addressed. Each pair presents the same features except of the instant the demand needs to be supplied, as it can be seen in Table 7.2 and Table 7.3.

In all pairs, the results show lower costs when non-uniform instant demand is considered. In all cases, the number of vehicles needed in order to realize the distribution of refrigerated products is reduced so the number of stores a vehicle visits increases. Hence, the average load of every vehicle also increases. Given that overall cost is reduced, it is interesting to see the reduction in every case. Here again, whether there are time restrictions or not makes a great difference.

On one hand, when time restrictions are not applied, that is to say, instances 1-3 and 5-7, a non-uniform instant demand represent savings of 3.2% and 2.1% respectively. Hence, its effect does not represent much. On the other hand, when there are time restrictions, the savings obtained when a non-uniform instant demand is considered are relevant. Given that there are time constraints, the savings obtained whether there is a uniform or non-uniform demand are the same, that is to say, pairs 2-4 and 6-8 present the same savings, 11.9%.

The third feature to analyze is the effect of time window. So far, it has already been presented some of its effects but it is interesting to address its repercussion with instances pairs 1-2, 3-4, 5-6, and 6-7. Each pair presents the same features except time window constraints, as it can be seen in Table 7.2 and Table 7.3.

As it has been stressed out, time window is the parameter with greater effects. As expected, in all cases the number of vehicles needed in order to run the distribution increases significantly, near doubling the number of routes, when there are time restrictions. Consequently, the number of stores visited per route and also the average load of the vehicles decreases significantly. Moreover, all pairs present higher cost when time restrictions are considered, between 39% and 56%. More precisely, when the instant demand is uniform, the effect of the time window is greater since pairs 1-2 and 5-6 present an increase of 53% and 56% in the cost, respectively. On the other hand, when the instant demand is not uniform, routes can be a more balanced and the increment of cost when considering time restrictions is lower. Instance pairs 3-4 and 7-8 present an increment of 39% and 41%, respectively.

Again, the statements are just applicable given the parameters implemented. With other values the results and conclusions obtained may change.

Before finishing the section is important to highlight that instances 2 and 6 present the same cost and routes but, given that the demand variable changes, the average load of every vehicle also changes. The same feature happens with instances 4 and 8. This fact is given by the great impact of the time window, since the freight must be delivered in a 30 minutes window. Hence, in order to see if the impact of the other two parameters, a longer time window is considered: 40 minutes. For that, instances 2, 4, 6 and 8 have been modified to 2', 4', 6' and 8' as seen in Table 7.4. The results obtained can be seen in Table 8.5.

| | 2' | 4' | 6' | 8' |
|---|---|---|---|---|
| **Number of routes** | 53 | 50 | 53 | 50 |
| **Average number of stores per vehicle** | 8.5 | 9 | 8.5 | 9 |
| **Average load per vehicle** | 101.9 | 108 | 101.4 | 107.6 |
| **Travel time cost** | 4529.25 | 4448.68 | 4529.25 | 4448.68 |

Table 8.5 Results of the instances 2', 4', 6', and 8' solved using the heuristic method.

The results show exactly the same feature, instances 2' and 6' present exactly the same results except of the average load per vehicle. The same aspect happens with instances 4' and 8'. Hence, although the delivery time is increased from 30 to 40 minutes, time restrictions are much important than other parameters, so their change is not noticeable.

Now, instances pairs 1-2', 3-4', 5-6', and 6-7' can also be compared. Each pair presents the same features except time window constraints, that 40 minutes window is considered instead of no restriction at all. Again, when there are time restrictions, the number of vehicles needed increases so the number of stores visited per vehicle decreases, and also its load. However, as expected, the number of vehicles needed is lower than when just 30 minutes delivery time is available. Moreover, all pairs also present higher cost when 40 minute time restriction is considered, between 27% and 30%. Hence, the increment of cost is much lower than when just 30 minutes are considered. In this case, the effect of a uniform instant demand does not have great impact since all pairs present more or less the same increment of cost. Instance pair 1-2' presents 27% increment in total cost, pair 3-4'

29%, pair 5-6' 30% and finally pair 7-8' also 30% increment in the total cost when 40 minutes delivery time is stablished.

Again, the statements are just applicable given the parameters implemented. With other values the results and conclusions obtained may change.

Moreover, a detailed solution of the routes of every subproblem can be found in the appendix.

Finally, it is important to note that the most common heuristic improvements cannot be applied since time plays an important role. Hence, no improvements have been implemented.

## 8.4 Results comparison

In this section, it is explained why the results obtained by using an exact method and the heuristic cannot be compared.

The near-optimal solution found is obtained by means of a solver that gives a solution according to the objective function stablished. As explained in Section 465.2.3 , the objective function does not just minimize the distance overcame but also punishes the use of a vehicle. Hence, there is a balance that the solver needs to take into account so the result will not probably be the one that results in lower distance travelled.

On the other hand, when implementing the heuristic, there is no restriction on the number of vehicles used and also no punishment for the use of one more vehicle. Hence, it just tries to optimize the distribution regarding distances, so the results should give shortest distance travelled.

Hence, it can be stated that, although using the same input data, since the aim is not exactly the same in both cases, both results cannot directly be compared.

In any case, it is interesting to observe that, although the near-optimal solution does not simply try to minimize the distance, when just the travel time cost is considered, it results a value of 3521.11 minutes. On the other hand, instance 7, the one that presents the same input data as the instance solved by CPLEX, gives a result of 3418.05 minutes. Hence, although the heuristic gives a better result, the result obtained by the exact method is very close, which could suggest that the heuristic performs good enough.

# Chapter 9: Conclusions and Future Work

## 9.1 Introduction

In this chapter, the resulting conclusions from the research investigation that has been carried out in the present master thesis are presented. These conclusions are divided in specific topics that have been studied in the distinct chapters. Moreover, the chapter also presents the main obstacles overcome when realizing the dissertation. To finish, this chapter contributes with several lines of research that could be used to orientate future research and application works.

## 9.2 Conclusions

In this section, the main conclusions withdrawn in the distinct chapters are presented.

### 9.2.1 Related to problem definition and modelling

Provisioning and replenishment of goods is essential for the success of Family Mart stores due to their size and features. Hence, the problem raised in this dissertation was to find a mathematical formulation to model the distribution of refrigerated products from the warehouse to the more than 450 Family Mart stores. Consequently, the problem was not just proposing a mathematical formulation but also implementing it, so a good routing distribution can be given.

In order to solve the problem, two resolution methods were proposed: optimal solution and heuristic method.

On one hand, two mathematical formulations were outlined in order to obtain the optimal solution: two-index formulation and three-index formulation. Both formulations have proved to give the same result. However, the number of variables, restrictions and computational time to obtain a solution using the three-index formulation is much greater than the two-index formulation. Hence, it can be stated that the two-index formulation is more efficient than the three-index one.

On the other hand, since finding an optimal solution has a high computational cost, a heuristic formulation is also defined in order to obtain a near-optimal solution. The heuristic is capable to give a solution that seeks to minimize the total travelled cost but does not punish the use of a larger fleet of vehicles. Hence, the aim is different from the one considered in the optimal solution.

### 9.2.2 Related to the implementation

Both resolution methods needed to be implemented in order to obtain a solution. For that, since the data provided was not the one needed, data treatment was necessary. After all the directions from more than 450 Family Mart stores were obtained, a tool was developed using the Distance Matrix API from Google services to retrieve the travel time matrix.

Regarding the implementation, it can be stated that implementing the optimal solution with CPLEX was not complicated since the language used is similar to how the mathematical formulation is written. Moreover, it could also be proven that the two-index formulation is much more efficient than the three-index one. Concerning heuristic implementation, it can be stated that it was quite complicated to implement it in Matlab because of the complexity and loops of the formulation. However, in both implementations, the results obtained from the solvers needed to be treated. Hence, not only the computational time needed to be considered but also the time needed to treat every solution.

#### *9.2.2.1 Optimal solution*

In order to obtain the optimal solution for the problem raised, the problem needed to be divided since its size was too large, so the original problem was split into 6 smaller problems. Consequently, although the result gave the optimal solution for every subproblem, it cannot be stated that overall optimal solution was found.

The implementation of the three-index formulation resulted to prove that theoretically is a good model but, since it uses a high number of variables, it can only be implemented in small instances. Hence, three-index formulation could not be used to obtain a solution for any of the subproblems raised.

On the other hand, the implementation of the two-index formulation was successful despite its high computational cost. The results obtained after 48 hours of running the solver were very similar to the one obtained after just running it for 5 hours. Consequently, it was imposed that just 5 hours would be enough to find a near-optimal solution for every subproblem. Therefore, without considering the treatment of the results, 30 hours were needed in order to get a solution for the overall problem. Hence, it can be stated that solving the problem raised by means of the optimal solution, although a near-optimal solution is given, is not efficient. Consequently, no assessment of the parameters used could be done.

The results from the different subproblems show that the cheapest or most expensive subproblem does not simply depend on the number of stores to be visited but mainly on their location. Consequently, although visiting a low number of stores, if the distances between them are high, a high cost results. Furthermore, if small clusters can be identified, although the distances between clusters can be large, overall cost is not that high. Finally, in order to obtain the routings for the problem raised, the routings and cost of every subproblem were added.

#### *9.2.2.2 Heuristic*

The implementation of the heuristic outlined, besides resulting to be easier to apply, is much more efficient since few seconds are needed in order to obtain a solution. Hence, different values for the demand, the instant of the demand and time window parameters were implemented in order to analyze their effect in the resulting routing.

The assessment of the demand to be delivered to every family store show that, when there are no time constraints, that is to say, when products can be delivered at any time, a non-uniform demand represents few savings, around 2%. Moreover, when delivery time is restricted, a non-uniform demand does not have any effect, since time restriction plays a more important role. Consequently, it can be stated that, in some cases, a non-uniform demand might represent savings, although not significant ones.

Regarding the impact of a uniform or non-uniform instant demand, that is to say, the moment the products must be delivered, results show that a non-uniform instant demand always present lower cost. On one hand, if no restriction concerning time is considered, just few savings are obtained, around 2%. On the other hand, when time restrictions are taken into account, the results present significant savings when a non-uniform instant demand is considered, around 12%. Consequently, it can be stated that a non-uniform instant demand always represent savings, more significant ones when time restrictions are applied.

Finally, the implementation of the heuristic also allowed to assess the impact of time restriction, that is to say, implement a time window for every Family Mart store. As expected, results show that when time restrictions are considered, the cost increases significantly, from 40 to 55%, approximately. The increment is more notable when a uniform instant demand is considered, about 55%. On the other hand, the increment of cost is around 40% when a non-uniform instant demand is considered since deliveries can be more balanced in time. Moreover, as expected, when time is less restricted, the increase of the of cost is smaller. In fact, when there is less time limitation, a change in the instant demand does not have any effect, since results show the sam increment. Hence, it can be stated that the effect of a non-uniform instant demand is more significant when time is more restricted. Overall, it can be stated that time windows is the parameter with greater effects.

#### *9.2.2.3 Comparison*

Last but not least, it is important to pinpoint that, as explained, the results cannot be directly compared since both methods have similar but different aims. However, the results obtained by means of the optimal solution do not just minimize the distance but balances it with the number of vehicle used. Hence, it can be understood that the optimal solution found is somehow more restricted, so the cost will always be higher than if only the distance would be minimized. Bearing this in mind, the result obtained by means of the heuristic does not differ much. Hence, although it cannot be said that the heuristic is a good method that provides a near-optimal solution because it cannot be directly compared, it can be stated that it performs good enough.

## 9.3 Problems to overcome

Before giving some insights on how to orientate future research, it is important to note the main difficulties overcome in this dissertation.

The first and most important time has been the time. The topic of the dissertation was decided when the visit of the warehouse took place. Consequently, approximately just three months and a half were available in order to build the thesis, from reviewing the related literature, creating the models, implementing them, analyzing the results and finally writing the thesis.

A second but also important issue has been the language. It has mainly been an obstacle when the location of the more than 450 Family Mart stores needed to be found, since all the names of the stores and, of course, road names, were in Chinese.

Finally, it is important to point that the data treatment, mainly the location of the stores but also the creation of the travel time matrix, required a lot of time. Hence, out of the few months available, too much time was devoted to basic steps, but at the same time steps needed in order to move forward. Consequently, less time was available to focus on the implementation of the methods and the analysis of the results.

## 9.4 Further work

First of all, in order to address the performance of the heuristic method, the aim of the optimal solution method would need to be modified to just minimize the distance travelled. Hence, both results could be compared so the quality of the heuristic could be assessed.

Moreover, improvement heuristics could be implemented in order to enhance the performance of the heuristic proposed, so the solution obtained is closer to the optimal one.

Finally, it would be interesting to better automatize the data treatment after a solution is obtained. Consequently, more results could be obtained and the effect of every parameter could be further studied.

# References


[1] Amap.com. (2018). *高德地图*. [online] Available at: https://www.amap.com/

[2] Calviño Martínez, A. (2011). *Cooperación en los problemas del viajante (TSP) y de rutas de vehículos (VRP): una panorámica*.

[3] Christofides, N. (1973). *The Optimum Traversal of a Graph*. Omega 1.

[4] Clarke, G. and Wright, J. (1964). *Scheduling of vehicles from a central depot to a number of delivery points.* Operations Research 12.

[5] Dantzig, G. and Ramser, J. (1959). *The truck dispatching problem*. Management Science.

[6] Darling, D. (2018). *Icosian Game*. [online] Daviddarling.info. Available at: http://www.daviddarling.info/encyclopedia/I/Icosian_Game.html

[7] Distribution to Family Mart. Pudong warehouse. (2017). Hitachi Transport System (China), Ltd.

[8] El-Sherbeny, N. (2009). *Vehicle routing with time windows: An overview of exact, heuristic and metaheuristic methods*. [ebook] Journal of King Saud University. Available at: https://www.sciencedirect.com/science/article/pii/S1018364710000297

[9] En.wikipedia.org. (2018). *FamilyMart*. [online] Available at: https://en.wikipedia.org/wiki/FamilyMart

[10] En.wikipedia.org. (2018). *Google APIs*. [online] Available at: https://en.wikipedia.org/wiki/Google_APIs

[11] En.wikipedia.org. (2018). *Millennium Prize Problems*. [online] Available at: https://en.wikipedia.org/wiki/Millennium_Prize_Problems

[12] En.wikipedia.org. (2018). *Seven Bridges of Königsberg*. [online] Available at: https://en.wikipedia.org/wiki/Seven_Bridges_of_K%C3%B6nigsberg

[13] En.wikipedia.org. (2018). *Unicharm*. [online] Available at: https://en.wikipedia.org/wiki/Unicharm

[14] En.wikipedia.org. (2018). *Vehicle routing problem*. [online] Available at: https://en.wikipedia.org/wiki/Vehicle_routing_problem

[15] Euler, L. (1736). *Solutio Problematis ad Geometrica Situs Pertinentis. Commentarii academiae scientarum Petropolitanae*.

[16] Familymart.com.cn. (2018). *全家Family Mart—开心尝鲜在全家 - 首页*. [online] Available at:
http://www.familymart.com.cn

[17] Fisher, M. and Jaikumar, R. (1981). *generalized assignment heuristic for vehicle routing*. Networks 11.

[18] Golden, B. and Wong, R. (1981). *Capacitated Arc Routing Problems.*. Networks 11.

[19] Google Cloud. (2018). *Google Maps Platform - Geo-location APIs ｜ Google Maps Platform ｜ Google Cloud*. [online] Available at:
https://cloud.google.com/maps-platform/

[20] Guan, M. (1962). *Graphic programming using odd or even points. Chinese Mathematics*.

[21] Hierholzer, C. (1873). *Über die endlichen und unendlichen Graphen. Akademische Verlagsgesellschaft.*. Leipzig.

[22] Ibm.com. (2018). *IBM Knowledge Center*. [online] Available at:
https://www.ibm.com/support/knowledgecenter/SSSA5P_12.6.0/ilog.odms.ide.help/OPL_Studio/opllang_quickref/topics/opl_quickref_whatis.html

[23] Ibm.com. (2018). *IBM Knowledge Center*. [online] Available at:
https://www.ibm.com/support/knowledgecenter/SSSA5P_12.7.0/ilog.odms.cplex.help/CPLEX/UsrMan/topics/preface/whatdoes.html

[24] Laporte, G. (2009). *Fifty years of vehicle routing*. Transportation Science.

[25] Laporte, G., Toth, P. and Vigo, D. (2018). *Vehicle routing: historical perspective and recent contributions*.

[26] Lenstra, J. and Rinnooy Kan, A. (1976). *On general routing problems*. Delft: Interuniversitaire interfaculteit bedrijfskunde.

[27] Lin, S. (1965). *An effective heuristic algorithm for the traveling-salesman problem*. Operation Research 21.

[28] Mathworld.wolfram.com. (2018). *Icosian Game -- from Wolfram MathWorld*. [online] Available at:
http://mathworld.wolfram.com/IcosianGame.html

[29] Min, W. (2010). *Rich Vehicle Routing Problems and Applications*. DTU Management Engineering.

[30] Nskeurope.com. (2018). *NSK - Home | Ball Bearings | Roller Bearings | Linear Components | Automotive Components*. [online] Available at: http://www.nskeurope.com/

[31] Orloff, C. (1974). *A Fundamental Problem in Vehicle Routing*. Networks 4.

[32] Puzzlemuseum.com. (2018). *Sir William Hamilton's Icosian Game and Traveller's Dodecahedron Puzzle.*. [online] Available at: https://www.puzzlemuseum.com/month/picm02/200207icosian.htm

[33] Shiseido.com. (2018). *SHISEIDO | Skincare, Makeup & Suncare*. [online] Available at: https://www.shiseido.com/

[34] Toth, P. and Vigo, D. (2002). *The Vehicle Routing Problem*. SIAM Monographs on Discrete Mathematics and Applications.

[35] Weber, A. (1929). *Theory of the location of industries*. Chicago: University of Chicago Press.

# Appendix

| ID | Shop Name | Adress | ID | Shop Name | Adress |
|---|---|---|---|---|---|
| 1 | 龙东大道店 | Xiangke Road | 41 | 北中路店 | 沪南路611-613号 |
| 2 | 盛夏路店 | Naxian Road | 42 | 莲园路店 | 上海市浦东新区世博大道1200号 |
| 3 | 盛夏路二店 | 龙东大道3000号1幢群楼102室 | 43 | 沪南公路二店 | 757号 Guo Zhan Lu |
| 4 | 秋月路店 | 盛夏路2号 | 44 | 世博大道店 | 上海市浦东新区海阳路646号 |
| 5 | 益江路店 | Haiqu Road | 45 | 长清北路店 | Shibo avenue metro station |
| 6 | 张衡路二店 | 上海市浦东新区张江镇华夏中路393号 | 46 | 世博大道站店 | Yaohua Road Station |
| 7 | 海趣路店 | Qiuyue Road | 47 | 国展路店 | 地铁8号线杨思路站 |
| 8 | 祥科路店 | 浦东新区张江镇益江路372-374号 | 48 | 耀华路站店 | 上南路800弄9号1楼D区 |
| 9 | 纳贤路店 | 张衡路666弄 | 49 | 上南路店 | Dongyu Road |
| 10 | 海趣路二店 | Haiqu Road | 50 | 杨思路店 | 上海轨道交通八号线凌兆新村站8-101号 |
| 11 | 华夏中路店 | 上海市浦东新区盛荣路188弄1号102室 | 51 | 海阳路店 | 国展路388号 |
| 12 | 盛荣路店 | 上海市浦东新区张江镇孙桥路202号 | 52 | 杨思路站店 | Sanlin East |
| 13 | 孙桥路店 | 张江镇盛夏路500号 | 53 | 东育路店 | 杨思路911号~913号 |
| 14 | 英伦路店 | Taizhong South Road | 54 | 凌兆新村站店 | 上南路3877号 |
| 15 | 台中南路店 | 台北西路168号 | 55 | 三林站店 | 上南路3768-3776号 |
| 16 | 杨高北路店 | 浦东新区季景路13号 | 56 | 上南路五店 | 上海轨道交通二号线世纪公园站店2-115 |
| 17 | 富特西一路店 | 大同路358号 | 57 | 上南路六店 | Century Park station |
| 18 | 光明路店 | 清溪路217号底层 | 58 | 世纪公园站店 | 浦东新区花木路800号一层C区 |
| 19 | 新园路店 | 上海市浦东新区高荷路488号 | 59 | 世纪公园站二店 | 锦延路332号一座A室 |
| 20 | 夏碧路店 | 高桥镇夏碧路278号 | 60 | 花木路店 | 锦康路258号2层202A、202B |
| 21 | 季景路店 | Qiulan Road | 61 | 锦延路店 | 崂山路715号1楼 |
| 22 | 大同路店 | 富特西一路479号 | 62 | 锦康路店 | 89 Hanqing Rd, Baoshan Qu, |
| 23 | 清溪路店 | 上海市浦东新区启帆路436号一层A室 | 63 | 崂山店 | 福山路450号1B-1 |
| 24 | 高荷路店 | No. 419, Guangming Road | 64 | 浦电路站店 | 向城路17号 |
| 25 | 夏碧路三店 | 上海市浦东新区新园路128弄47号 | 65 | 双鸽大厦店 | 崂山路528号(紫金山大酒店内) |
| 26 | 秋岚路店 | 浦东新区夏碧路26号 | 66 | 福山路店 | 福山路455号全华信息大厦一楼106室 |
| 27 | 启帆路店 | 东靖路669弄38号 | 67 | 向城店 | 826 Beijing E Rd, Huangpu Qu |
| 28 | 东煦路店 | 4号线蓝村路站-4-104 | 68 | 紫金山店 | Shanghai Science |
| 29 | 蓝村路站店 | 上海市浦东新区峨山路91弄 | 69 | 福山路二店 | 二号线科技馆站2-101 |
| 30 | 峨山店 | 梅花路6号 | 70 | 科技馆站四店 | 迎春路763号（足浴） |
| 31 | 梅花路二店 | 上海市浦东新区东绣路300号 | 71 | 科技馆站五店 | 民生路1518号A楼103室 |
| 32 | 东绣路二店 | 东建路217号 | 72 | 科技馆站二店 | 迎春路880号 |
| 33 | 东建路二店 | 36号 Jin An Dong Lu | 73 | 金鹰大厦店 | 迎春路1130号 |
| 34 | 锦安东路店 | Mu Dan Lu, ShiJi GongYuan | 74 | 迎春路三店 | 丁香路1197号（杏花楼) |
| 35 | 东建路三店 | 地铁7号线芳华路站-7-101 | 75 | 迎春店 | 民生路1199弄1号 |
| 36 | 牡丹路店 | 芳华路511号（震轩） | 76 | 迎春二店 | 羽山路402-406号 |
| 37 | 芳华路站店 | 莲溪路508号 | 77 | 丁香路店 | 民生路628号（航运科研大厦) |
| 38 | 芳华路店 | 五星路364号 | 78 | 民生路六店 | 民生路628号（航运科研大厦) |
| 39 | 莲溪路店 | 北中路187弄21号 | 79 | 羽山路二店 | 羽山路78号 |
| 40 | 五星路店 | 莲园路路190号 | 80 | 民生路五店 | 松林路289号 |

Table 1. Addresses of Shanghai Family Mart stores. Part 1.

| ID | Shop Name | Adress |
|---|---|---|
| 81 | 张杨二店 | 浦东新区浦电路577号1楼01B室 |
| 82 | 羽山店 | 线东陆路站 |
| 83 | 松林路店 | 东波路239号 |
| 84 | 葛洲坝大厦店 | 上海市浦东新区五莲路608号 |
| 85 | 东陆路站店 | 五莲路697号 |
| 86 | 东波路店 | 上海市徐汇区桂林路515号(钦江路,华利公寓, |
| 87 | 五莲路二店 | 佳林路175号 |
| 88 | 五莲路店 | 上海市浦东新区轨道交通12号线金京路站12- |
| 89 | 佳林路二店 | 上海轨道交通12号线申江路站 |
| 90 | 佳林路店 | 浦东新区金高路1100号 |
| 91 | 金京路站店 | 金桥路1359号 |
| 92 | 申江路站店 | 新金桥路27号 |
| 93 | 金高路店 | 新金桥路230号 |
| 94 | 金桥路店 | 上海市浦东新区新金桥路230号 |
| 95 | 新金桥二店 | 浙桥路200号J2-102 |
| 96 | 川桥路店 | 地铁3号线赤峰路站3-206 |
| 97 | 新金桥三店 | 地铁3号线赤峰路站3-202 |
| 98 | 新金桥路五店 | 广灵一路40号 |
| 99 | 浙桥路店 | 中山北路470号 |
| 100 | 大柏树站店 | 天通庵路796号 |
| 101 | 赤峰路站二店 | 东江湾路444号5号门 |
| 102 | 赤峰路站店 | 祥德路139弄2号底层 |
| 103 | 广灵一路店 | 彰武路同济大厦A楼东侧 |
| 104 | 中山北一路四 | 花园路66弄1号102 |
| 105 | 花园路店 | 8号线曲阳路站（6号口） |
| 106 | 虹口足球场站 | 玉田路333号 |
| 107 | 天通庵路店 | 虹口区东体育会路411号（甲） |
| 108 | 虹口足球场店 | 地铁3号线江湾镇-3-201A |
| 109 | 祥德路店 | 上海市虹口区水电路1382号 |
| 110 | 四平路四店 | 轨道交通8号线虹口足球场站1001房 |
| 111 | 曲阳路站店 | 新市南路772号 |
| 112 | 玉田二店 | 平型关路130号 |
| 113 | 东体育会路店 | 上海市虹口区车站南路434-4号 |
| 114 | 江湾镇站店 | 931 siping road |
| 115 | 车站北路店 | 天宝路556号101室 |
| 116 | 新市南路店 | Ruihong Road |
| 117 | 水电路店 | 上海市虹口区瑞虹路188号 |
| 118 | 车站南路店 | 临平路133号瑞虹新 |
| 119 | 四平路站店 | 虹口区安国路350号 |
| 120 | 天宝路二店 | 飞虹路393号底层 |
| 121 | 瑞虹路二店 | 临平路64号 |
| 122 | 瑞虹路店 | 临平北路55号一层C室 |
| 123 | 临平路站店 | 临平路64号 |
| 124 | 安国路店 | 大连路1548号 |
| 125 | 飞虹路店 | 延安东路550号 |
| 126 | 临平路店 | 延安东路588号 |
| 127 | 临平北路店 | 上海轨道交通二号线人民广场站2-135 |
| 128 | 物华路店 | 上海市轨道交通一号线人民广场站1-114 |
| 129 | 临平店 | 地铁2号线人民广场站2-107-109 |
| 130 | 大连路五店 | 南京西路108号 |
| 131 | 延安东路二店 | Hongxiang Mansion |
| 132 | 延安东路四店 | 北京西路3-5号 |
| 133 | 人民广场站二 | Century Park station |
| 134 | 人民广场站三 | 牛庄路781号 |
| 135 | 人民广场站店 | 浙江中路454号 |
| 136 | 南京西路六店 | 上海市黄浦区西藏中路500号思源商厦1层 |
| 137 | 鸿祥大厦店 | 广东路495号 |
| 138 | 新金桥广场店 | 福建中路363号 |
| 139 | 西藏中路店 | 北京东路786号 |
| 140 | 牛庄路店 | 长阳路245号 |

| ID | Shop Name | Adress |
|---|---|---|
| 141 | 浙江中路二店 | 霍山路9号底层 |
| 142 | 广西北路店 | Tilanqiao Station |
| 143 | 广东路二店 | 高阳路109号 |
| 144 | 福建中路店 | 四川北路479号 |
| 145 | 北京东路店 | Tiantong Road station |
| 146 | 长阳店 | Dongbaoxing Road |
| 147 | 霍山路店 | 四川北路1885号101-C |
| 148 | 提篮桥站店 | 上海轨道交通10号线四川北路站10-101 |
| 149 | 高阳路店 | 海宁路307号 |
| 150 | 四川北路店 | 黄浦路110号 |
| 151 | 天潼路站店 | 四川北路1495号 |
| 152 | 海伦路站店 | 大名路137号 |
| 153 | 四川北路站店 | 上海市黄浦区云南南路260号1层 |
| 154 | 四川北路二店 | 人民路885号 |
| 155 | 东宝兴路站店 | （豫园街道）人民路399号 |
| 156 | 四川北路五店 | 上海市静安区中华新路567号 |
| 157 | 海宁路店 | Laotaiping Long |
| 158 | 黄浦路店 | 金陵东路33号 |
| 159 | 大名路店 | #¿NOMBRE? |
| 160 | 云南南路二店 | 汉口路477～479号 |
| 161 | 人民路店 | 南京西路338号 |
| 162 | 人民路三店 | 凤阳路310号-1 |
| 163 | 中华路三店 | east nanjing road metro |
| 164 | 老太平弄店 | 183 Shanxi S Rd |
| 165 | 金陵东路二店 | 川图路300号 |
| 166 | 河南中路二店 | 上海轨道交通16号线野生动物园站16-101 |
| 167 | 南京东路站店 | Xuanzhong Road |
| 168 | 南京东路二店 | Huinan station |
| 169 | 汉口路店 | Huinan station |
| 170 | 南京西路五店 | 人民东路2981-2983号 |
| 171 | 凤阳路店 | 环城东路610号 |
| 172 | 川图路店 | 祝桥镇东大街39号 |
| 173 | 野生动物园站店 | 上海市浦东新区祝桥镇华星路337号 |
| 174 | 宣中路店 | Chao Hui Lu, Pudong Xinqu, Shanghai Shi, Xir |
| 175 | 惠南站二店 | 东亭路519号 |
| 176 | 惠南站店 | 湖滨路222号 |
| 177 | 人民东路三店 | Huangpi south road station |
| 178 | 人民东路二店 | 黄埔区淮海中路1号（淮海中路柳林路 |
| 179 | 上飞路店 | 上海市黄浦区馆驿街42号 |
| 180 | 千汇路店 | 上海市浦东新区千汇路557-559号 |
| 181 | 百熙路店 | Zhongshan East 2nd Road |
| 182 | 东大街店 | 浦东惠南镇人民东路2677-2681号 |
| 183 | 华星路店 | 百熙路366号 |
| 184 | 东亭路店 | 黄浦区四川南路32号 |
| 185 | 湖滨路店 | 河南中路505号-2 |
| 186 | 黄陂南路站店 | 四川中路435号 |
| 187 | 普安路店 | 福州路53号 |
| 188 | 淮海中路四店 | Luheng road metro station |
| 189 | 馆驿街店 | 浦东新区杨高南路5678弄38号 |
| 190 | 中山东二路店 | 上海市浦东新区周浦镇上南路6881号 |
| 191 | 四川南路店 | 沪南公路3439弄15号1层1-2室 |
| 192 | 河南中路三店 | 康沈路1746号 |
| 193 | 四川店 | 南汇区周浦镇年家浜路237号 |
| 194 | 福州店 | 年家浜路235号 |
| 195 | 芦恒路站店 | 上海市浦东新区秀沿路1181号 |
| 196 | 杨高南路二店 | 秀沿路2575-1号 |
| 197 | 上南路七店 | 关岳路155号 |
| 198 | 沪南公路店 | 上海市浦东新区川周公路2876号附近 |
| 199 | 关岳西路店 | 中山南一路302号 |
| 200 | 康沈路二店 | 蒙自路527号 |

Table 2. Addresses of Shanghai Family Mart stores. Part 2.

| ID | Shop Name | Adress |
|---|---|---|
| 201 | 康沈路店 | 小木桥路316号 |
| 202 | 年家浜路店 | 制造局路287号 |
| 203 | 年家浜路二店 | lujiaband road station |
| 204 | 周市路店 | 264号 Zhou Zhu Gong Lu |
| 205 | 关岳路店 | lujiaband road station |
| 206 | 年家浜东路店 | 瑞金二路388号 |
| 207 | 周园路店 | 瑞金二路197号 |
| 208 | 周祝公路店 | 瑞金二路130号乙 |
| 209 | 秀沿路二店 | 年家浜东路159弄65号 |
| 210 | 秀沿路店 | 瑞金二路33号 |
| 211 | 川周公路店 | 周园路1501号-3-4室（周浦医院对面） |
| 212 | 中山南一路二 | 西藏南路1739弄 |
| 213 | 蒙自路店 | 浦东新区（六里）东三里桥路1018号AB座1层 |
| 214 | 斜土路八店 | 建国西路135号（靠近陕西南路） |
| 215 | 制造局路店 | 上海市浦东新区浦三路61号 |
| 216 | 陆家浜路站店 | Gaoke West Road Station |
| 217 | 陆家浜路站二店 | 浦建路727号 |
| 218 | 瑞金路二店 | 浦建路145号 |
| 219 | 瑞金二路店 | 南泉路1358号 |
| 220 | 瑞金店 | 浦东南路2100号一层南 |
| 221 | 瑞金二路六店 | 临沂北路150弄2号 |
| 222 | 建西店 | Lancun Road 48 |
| 223 | 西藏南路八店 | Lushan Road |
| 224 | 东三里桥路店 | 东方路989号105室 |
| 225 | 浦三路店 | 杨高南路428号B2层01室 |
| 226 | 高科西路站店 | 陆家浜路1055号面包房 |
| 227 | 浦建路三店 | 西藏南路916号 |
| 228 | 强生大厦店 | 瑞金二197号瑞金医院15号楼 |
| 229 | 南泉路二店 | 徐家汇路618号 |
| 230 | 浦东南路四店 | Dapuqiao station |
| 231 | 临沂北路店 | 斜徐路579号 |
| 232 | 蓝村路二店 | 鲁班路400弄9号 |
| 233 | 峨山路二店 | 中山南一路922号107室 |
| 234 | 东方店 | 鲁班路357号 |
| 235 | 杨高南路店 | 局门路436号 |
| 236 | 陆家浜路店 | 丽园路506号 |
| 237 | 西藏南路四店 | 制造局路1号 |
| 238 | 瑞金二路二店 | 上海市浦东新区松涛路560号 |
| 239 | 徐家汇路一店 | 科苑路399号 |
| 240 | 打浦桥站店 | 金科路2966号 |
| 241 | 斜徐路店 | 哈雷路918号 |
| 242 | 鲁班路二店 | 华佗路280弄31号1楼 |
| 243 | 中山南一路店 | 华佗路562号564号 |
| 244 | 鲁班路四店 | 华佗路1号 |
| 245 | 局门路二店 | 科苑路201号 |
| 246 | 局门三店 | 李时珍路421号 |
| 247 | 丽园路店 | 郭守敬路669号 |
| 248 | 丽园路二店 | 晨辉路1000号 |
| 249 | 制造局路二店 | 建中路254号 |
| 250 | 松涛路店 | 银山路363号1层 |
| 251 | 创新园店 | 上海市浦东新区枣庄路567号附近 |
| 252 | 金科路二店 | 上海市浦东新区栖山路1638号 |
| 253 | 哈雷路店 | 博山东路140号 |
| 254 | 华佗路四店 | 德平路26号 |
| 255 | 华佗路二店 | 德平路1145号 |
| 256 | 华佗路三店 | 建中路103号 |
| 257 | 科苑路店 | 灵山路仁济北院 |
| 258 | 日月光店 | 上海市浦东新区灵山路721号1层 |
| 259 | 郭守敬店 | 浦东新区陆家嘴环路1318号B107室 |
| 260 | 晨晖路店 | 浦东大道1022号 |

| ID | Shop Name | Adress |
|---|---|---|
| 261 | 建中路店 | 乳山路209号 |
| 262 | 建中路二店 | 上海市浦东新区张江镇紫薇路693号 |
| 263 | 紫薇路店 | Boxia Road |
| 264 | 博霞路店 | 碧云路1146号 |
| 265 | 碧云店 | 浦电路438号106A室 |
| 266 | 银山路店 | 张杨路1592号 |
| 267 | 张杨路九店 | 张杨路1681-2号 |
| 268 | 栖山路店 | 上海市浦东新区云雅路392号1层 |
| 269 | 博山东路店 | yuyuan garden station |
| 270 | 德平路店 | 宁海东路232号 |
| 271 | 德平路二店 | 云南中路53-55号 |
| 272 | 灵山路店 | Dashijie station |
| 273 | 灵山路二店 | Dashijie station |
| 274 | 陆家嘴环路店 | 金陵中路187号 |
| 275 | 浦东大道店 | 淮海中路300号 |
| 276 | 乳山路二店 | 建国中路10号8号楼8102， 8103室 |
| 277 | 张杨三店 | 世纪大道1600号 |
| 278 | 张杨六店 | 浦东大道1号 |
| 279 | 来安路店 | 银城路9,55,99号 |
| 280 | 云雅路店 | Hesha hangcheng station |
| 281 | 豫园站店 | 英伦路889号 |
| 282 | 宁海东路店 | 崂山路56号 |
| 283 | 云南店 | 浦东大道720号B1 |
| 284 | 大世界站店 | 东方路18号103室 |
| 285 | 大世界站二店 | 陆家嘴环路958号 |
| 286 | 黄陂北路店 | 银城中路8号 |
| 287 | 重庆北路店 | 陆家嘴西路168号B1层21-22 |
| 288 | 金陵中路店 | 富城路99号 |
| 289 | 淮海中路三店 | 银城中路501号 |
| 290 | 建国中路店 | 银城中路488号 |
| 291 | 世纪大道二店 | 世纪大道100号上海环球 |
| 292 | 船舶大厦店 | 上海市浦东新区上丰路1288号 |
| 293 | 银城路店 | Yanggao North Road station |
| 294 | 新上海国际大厦 | Jufeng Road Station |
| 295 | 世纪大道店 | 新行路 |
| 296 | 崂山路四店 | 俱进路67号 |
| 297 | 航运大厦店 | Caolu pudong |
| 298 | 保利广场店 | 顾唐路136号 |
| 299 | 华能大厦店 | 金海路2727号 |
| 300 | 银城中路店 | 上海市浦东新区民耀路453号1-2层 |
| 301 | 正大广场店 | 上海市浦东新区民耀路235号1层 |
| 302 | 震旦店 | 上川路1111号 |
| 303 | 银城中路二店 | 上海市浦东新区曹路镇民雨路390号1楼10 |
| 304 | 太平金融大厦店 | 上丰路1838号 |
| 305 | 环球金融中心二 | 仁庆路388号 |
| 306 | 上丰路二店 | 浦东新区新德路977号 |
| 307 | 杨高北路站店 | 华夏二路651号 |
| 308 | 巨峰路站店 | 新川路589号 |
| 309 | 新行路店 | 新川路236号 |
| 310 | 俱进路店 | 5095 Chuansha Rd |
| 311 | 金海路四店 | Chuansha station |
| 312 | 顾唐路店 | 上海市浦东新区新川路911号 |
| 313 | 金海路店 | Chuanhuang Rd |
| 314 | 民耀路店 | 翔川路409号 |
| 315 | 民耀路二店 | 南桥路977号 |
| 316 | 上川路店 | 进贤路192号 |
| 317 | 民雨路店 | 浦东新区川沙镇新德路637号 |
| 318 | 上丰路店 | 上海市浦东新区瑞浦路612弄11幢28号-1 |
| 319 | 仁庆路店 | 张江路18号4楼 |
| 320 | 龙桂路店 | 丽园路867号 |

Table 3. Addresses of Shanghai Family Mart stores. Part 3.

| ID | Shop Name | Adress |
|---|---|---|
| 321 | 新德路店 | 上海市浦东新区航头路1115号附近 |
| 322 | 华夏二路店 | Jiang Wen Road 70 |
| 323 | 新川路二店 | 3872 Shendu Hwy |
| 324 | 新川路店 | 浦锦路309弄165号 |
| 325 | 川沙路店 | 上海市闵行区浦驰路195-199号 |
| 326 | 川沙站店 | 江月路1850弄1号1层A02-01 |
| 327 | 川环南路店 | 浦东新区（三林）永泰路182号 |
| 328 | 川黄路店 | 永泰路499号 |
| 329 | 翔川路店 | 环林东路283号 |
| 330 | 南桥路二店 | 御桥路268号 |
| 331 | 进贤路店 | 御桥路1966号 |
| 332 | 新德路二店 | 张东路1558号 |
| 333 | 唐镇路店 | 张江路18号 |
| 334 | 瑞浦路店 | 东建路909号 |
| 335 | 鹤沙航城站店 | 兰花路231号 |
| 336 | 沪南公路四店 | 银霄路288号1层 |
| 337 | 航头路店 | 上海市浦东新区梅花路776号 |
| 338 | 江文路店 | 花木路1378号 |
| 339 | 昌达路店 | 祖冲之路2889弄 |
| 340 | 浦锦路店 | 南车站路356号 |
| 341 | 浦驰路店 | 西藏南路1521号 |
| 342 | 江月路店 | 西藏南路1485号1层 |
| 343 | 永泰路三店 | 瞿溪路1005号 |
| 344 | 永泰路二店 | 打浦路208号 |
| 345 | 环林东路店 | 雁荡路92号 |
| 346 | 御桥路二店 | 雁荡路20号 |
| 347 | 御桥路店 | 四川北路1350号109室 |
| 348 | 张东路店 | 中华路1302-1304号 |
| 349 | 中芯二店 | 上海市黄浦区陆家浜路770号(陆家浜路与河 |
| 350 | 中芯店 | 中华路856号一层 |
| 351 | 梅花路店 | 金坛路30号 |
| 352 | 兰花路店 | 上海市浦东新区金皖路56号 |
| 353 | 银霄路店 | 金海路1000号 |
| 354 | 梅花路三店 | 新金桥路1888号 |
| 355 | 花木路二店 | 上海市浦东新区金豫路450号 |
| 356 | 金科路三店 | 黄浦区大吉路277号 |
| 357 | 南车站路店 | 浦东新区金湘路201弄17号一层 |
| 358 | 西藏南路二店 | 新金桥路1088号B104室 |
| 359 | 西藏南路六店 | 上海市浦东新区金高路1802号 |
| 360 | 瞿溪路店 | 博兴路1479-1484号 |
| 361 | 打浦路三店 | 博兴路907号底层 |
| 362 | 南昌路店 | 上海市浦东新区荷泽路630号 |
| 363 | 雁荡路店 | 上海市浦东新区长岛路748号 |
| 364 | 吉安路店 | 兰城路239号 |
| 365 | 大吉路店 | Boxing Road Station |
| 366 | 中华路二店 | 上海市浦东新区五莲路1703号 |
| 367 | 陆家浜路二店 | 宁桥路888号 |
| 368 | 中华路店 | 利津路1297号 |
| 369 | 金坛路店 | 武进路288号 |
| 370 | 金皖路店 | 浦东新区川桥路401号 |
| 371 | 金海路二店 | 年家浜路346号 |
| 372 | 新金桥路四店 | 东宝兴咱249号 |
| 373 | 金豫路店 | 上海市虹口区甘河路191号 |
| 374 | 宁桥路店 | 逸仙路17号 |
| 375 | 金湘路店 | 曲阳路930号A幢105室 |
| 376 | 中惠广场店 | 万安路243号1楼 |
| 377 | 金沪路店 | Zhongshan North Road |
| 378 | 博兴路店 | Shanghai Pudong International Airport Terminal |
| 379 | 博兴路二店 | Pudong Airport Terminal 2 |
| 380 | 荷泽路店 | Pudong Airport Terminal 2 |
| 381 | 长岛路店 | Shanghai Pudong International Airport Termi |
| 382 | 兰城路店 | Shanghai Pudong International Airport Termi |
| 383 | 博兴路三店 | Cifu Pudong Airport Station |
| 384 | 五莲路三店 | Shanghai Pudong International Airport Termi |
| 385 | 利津路店 | Cifu Pudong Airport Station |
| 386 | 武进路店 | 浦东南路1529号 |
| 387 | 四川北路九店 | 成山路288号 |
| 388 | 四川北路十店 | 祖冲之路2288弄 |
| 389 | 东宝兴路店 | 上南路1489-1号 |
| 390 | 东宝兴路二店 | 浦东南路3917号 |
| 391 | 宝通店 | 上海市浦东新区板泉路2180号 |
| 392 | 赤峰路二店 | 成山路2164号 |
| 393 | 甘河路店 | 成山路2583-2585号 |
| 394 | 逸仙路二店 | 上海市浦东新区下南路大华·锦绣华城11街 |
| 395 | 逸仙路三店 | 上海市浦东新区盛夏路58弄23号 |
| 396 | 万安店 | 浦东新区（北蔡）北艾路897号 |
| 397 | 中山北一路三店 | 青桐路181号 |
| 398 | 迎宾大道二店 | 浦东南路855号1层1D座(世界广场内) |
| 399 | 迎宾大道七店 | 龙阳路2345号E馆 |
| 400 | 迎宾大道六店 | 龙阳路2345号 |
| 401 | 迎宾大道五店 | 东昌路459号 |
| 402 | 迎宾大道三店 | 浦东南路1101号1层A6 |
| 403 | 浦东机场三店 | 南泉北路1029号1层 |
| 404 | 浦东机场二店 | 张杨路500号1层119室 |
| 405 | 浦东机场店 | 潍坊西路56号 |
| 406 | 祖冲之路二店 | 浦电路337号 |
| 407 | 盛夏路三店 | 东方路912号 |
| 408 | 青桐路店 | 张杨路1041号 |
| 409 | 浦东南路六店 | 张扬路2057号 |
| 410 | 成山路店 | 民生路600号 |
| 411 | 上南二店 | 苗圃路162号 |
| 412 | 浦东南路五店 | 浦东新区博山路122号 |
| 413 | 板泉路店 | 张杨路640号 |
| 414 | 成山路二店 | 浦东新区陆家嘴环路1318号B107室 |
| 415 | 成山路三店 | Longyang Road Station |
| 416 | 下南路店 | 崂山路600号一层D区 |
| 417 | 北艾路店 | 上海市浦东新区浦建路218号 |
| 418 | 芳甸路店 | 上海市浦东新区东方路1630号3号楼B1层4 |
| 419 | 博览中心二店 | 方斜路18号 |
| 420 | 博览中心店 | 尚文路191号 |
| 421 | 潍坊店 | 上海市黄浦区普育西路国货路309号 |
| 422 | 浦东南路店 | Bibo Road |
| 423 | 东昌路店 | 祖冲之路899号 |
| 424 | 浦东南路二店 | 天宝路881号2号楼101 |
| 425 | 南泉北路店 | 河南南路33号 |
| 426 | 张杨路八店 | 福山路500号 |
| 427 | 张杨店 | Jinhai road station |
| 428 | 崂山三店 | 万安路521号 |
| 429 | 浦电路二店 | 浦电路337号 |
| 430 | 东方三店 | 东方路912号 |
| 431 | 张扬四店 | 张杨路1041号 |
| 432 | 张扬路七店 | 张扬路2057号 |
| 433 | 民生路四店 | 民生路600号 |
| 434 | 苗圃路店 | 苗圃路162号 |
| 435 | 博山路店 | 浦东新区博山路122号 |
| 436 | 浦东南路七店 | 西藏南路1208号 |
| 437 | 龙阳路站三店 | Longyang Road Station |
| 438 | 浦建路四店 | 上海市浦东新区浦建路218号 |
| 439 | 东方路四店 | 上海市浦东新区东方路1630号3号楼B1层4 |
| 440 | 方斜路店 | 方斜路18号 |

Table 4. Addresses of Shanghai Family Mart stores. Part 4.

| ID | Shop Name | Adress | ID | Shop Name | Adress |
|---|---|---|---|---|---|
| **441** | 尚文路店 | 尚文路191号 | **446** | 天宝路店 | 物华路308号底层 |
| **442** | 西藏南路三店 | 西藏南路1208号 | **447** | 河南南路二店 | 关岳西路13号 |
| **443** | 国货路店 | 上海市黄浦区普育西路国货路309号 | **448** | 城建店 | 局门路541号 |
| **444** | 碧波路店 | Bibo Road | **449** | 金海路三店 | 康沈路1935号 |
| **445** | 祖冲之店 | 祖冲之路899号 | **450** | 万安路二店 | 花木街道芳甸路1201号 |

Table 5. Addresses of Shanghai Family Mart stores. Part 5.

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 7 | 20 | 48 | 8 | 11 | 6 | 4 | 5 | 16 | 3 | 56 | 57 | | | | | |
| **Route 1** | Arrival time | 37.12 | 39.55 | 45.05 | 50.18 | 51.4 | 55.68 | 59.33 | 59.33 | 61.71 | 67.29 | 73.62 | 76.8 | | | | | |
| | Vehicle load | 13 | 29 | 43 | 57 | 73 | 83 | 93 | 102 | 113 | 126 | 138 | 151 | | | | | |
| | Nodes | 28 | 33 | 61 | 23 | 24 | 25 | 27 | 26 | 32 | 29 | 30 | 12 | 14 | 15 | 55 | 58 | 13 |
| **Route 2** | Arrival time | 25.37 | 32.24 | 35.86 | 36.84 | 38.62 | 39.32 | 41.92 | 44.75 | 44.95 | 44.95 | 46.75 | 51.8 | 55.88 | 56.48 | 69.12 | 74.87 | 82.8 |
| | Vehicle load | 8 | 20 | 30 | 44 | 55 | 66 | 75 | 87 | 99 | 111 | 121 | 130 | 142 | 157 | 170 | 185 | 195 |
| | Nodes | 17 | 21 | 18 | 19 | 62 | 59 | 2 | | | | | | | | | | |
| **Route 3** | Arrival time | 22.47 | 36.29 | 37.59 | 39.64 | 41.79 | 43.46 | 64.11 | | | | | | | | | | |
| | Vehicle load | 11 | 24 | 36 | 49 | 60 | 73 | 82 | | | | | | | | | | |
| | Nodes | 35 | 34 | 39 | 38 | 47 | 46 | 31 | 37 | 36 | | | | | | | | |
| **Route 4** | Arrival time | 45.8 | 49.27 | 58.47 | 60.2 | 63.8 | 64.9 | 69.39 | 81.52 | 85.1 | | | | | | | | |
| | Vehicle load | 15 | 26 | 38 | 51 | 64 | 78 | 89 | 98 | 111 | | | | | | | | |
| | Nodes | 44 | 9 | 10 | 43 | 53 | 52 | 42 | 50 | 51 | 41 | 49 | 45 | 40 | 22 | 54 | 60 | |
| **Route 5** | Arrival time | 39.91 | 46.51 | 49.46 | 52.84 | 55.67 | 56.04 | 57.74 | 58.71 | 59.04 | 59.04 | 59.49 | 61.62 | 65.64 | 67.54 | 72.51 | 85.56 | |
| | Vehicle load | 9 | 21 | 36 | 51 | 65 | 76 | 90 | 102 | 115 | 129 | 141 | 157 | 165 | 178 | 191 | 199 | |

Table 6. Routing detail of Group 1 (Yellow).

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 26 | 16 | 25 | 36 | 24 | 20 | 66 | 93 | 23 | 73 | 37 | 22 | 38 | 15 | 4 | | |
| **Route 1** | Arrival time | 32.37 | 34.89 | 37.36 | 39.38 | 39.86 | 46.24 | 51.94 | 53.32 | 54.22 | 57.27 | 61.24 | 63.97 | 66.95 | 70.87 | 84.21 | | |
| | Vehicle load | 12 | 23 | 34 | 47 | 58 | 74 | 85 | 97 | 111 | 123 | 132 | 145 | 158 | 173 | 183 | | |
| | Nodes | 27 | 71 | 72 | 28 | 10 | 9 | 8 | 7 | 6 | 69 | 70 | 67 | 35 | 65 | | | |
| **Route 2** | Arrival time | 31.68 | 34.7 | 36.03 | 39.81 | 40.44 | 42.56 | 44.68 | 44.68 | 44.68 | 48.86 | 48.86 | 49.98 | 54.56 | 69.33 | | | |
| | Vehicle load | 9 | 20 | 33 | 41 | 56 | 68 | 82 | 95 | 105 | 118 | 128 | 139 | 154 | 172 | | | |
| | Nodes | 42 | 91 | 63 | 60 | 61 | 40 | 79 | 62 | 86 | 64 | 44 | 43 | 19 | 89 | 83 | 75 | 56 |
| **Route 3** | Arrival time | 25.4 | 27.83 | 30.63 | 33.65 | 34.58 | 41.71 | 42.96 | 45.93 | 48.28 | 48.58 | 52 | 52 | 58.2 | 60.8 | 63.87 | 71.24 | 73.62 |
| | Vehicle load | 14 | 29 | 39 | 47 | 57 | 65 | 78 | 89 | 100 | 112 | 121 | 136 | 149 | 161 | 173 | 184 | 196 |
| | Nodes | 48 | 81 | 82 | 30 | 74 | 29 | 31 | 32 | 18 | | | | | | | | |
| **Route 4** | Arrival time | 31.58 | 33.35 | 34.15 | 36.53 | 37.68 | 40.76 | 44.16 | 79.74 | 81.31 | | | | | | | | |
| | Vehicle load | 14 | 26 | 35 | 45 | 58 | 70 | 81 | 93 | 105 | | | | | | | | |
| | Nodes | 59 | 57 | 58 | 39 | 50 | 77 | 78 | 76 | 92 | 51 | 90 | 85 | 84 | 52 | | | |
| **Route 5** | Arrival time | 25 | 26.47 | 29.37 | 31.52 | 35.15 | 37.75 | 38.03 | 40.81 | 43.24 | 45.79 | 48.39 | 50.76 | 73.62 | 75.54 | | | |
| | Vehicle load | 13 | 26 | 41 | 53 | 65 | 75 | 86 | 101 | 113 | 126 | 138 | 148 | 159 | 170 | | | |
| | Nodes | 80 | 45 | 47 | 55 | 54 | 41 | 3 | | | | | | | | | | |
| **Route 6** | Arrival time | 28.6 | 34.8 | 34.8 | 43.57 | 45.07 | 51.49 | 84.87 | | | | | | | | | | |
| | Vehicle load | 13 | 29 | 42 | 55 | 68 | 82 | 95 | | | | | | | | | | |
| | Nodes | 87 | 88 | 21 | 34 | 33 | 5 | 68 | 14 | 12 | 13 | 17 | 2 | 11 | 53 | 49 | 46 | |
| **Route 7** | Arrival time | 27.59 | 30.46 | 34.03 | 38.3 | 40.87 | 43.12 | 44.04 | 48.24 | 48.92 | 50.15 | 53.32 | 53.49 | 55.47 | 67.24 | 71.21 | 73.66 | |
| | Vehicle load | 9 | 20 | 33 | 44 | 56 | 65 | 76 | 88 | 97 | 107 | 118 | 127 | 143 | 157 | 169 | 183 | |

Table 7. Routing detail of Group 2 (Brown).

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 10 | 73 | 37 | 72 | 14 | 81 | 74 | 52 | 46 | 34 | 50 | 51 | 41 | 78 | 76 | 26 | |
| **Route 1** | Arrival time | 60.93 | 31.4 | 52 | 33.16 | 22.12 | 59.64 | 26.87 | 67.86 | 73.34 | 57.72 | 45.12 | 63.83 | 51.37 | 60.36 | 20.65 | 60.58 | |
| | Vehicle load | 15 | 27 | 36 | 49 | 61 | 73 | 86 | 97 | 111 | 122 | 134 | 147 | 161 | 172 | 187 | 199 | |
| | Nodes | 13 | 15 | 12 | 82 | 11 | 17 | 16 | 8 | 4 | 5 | 9 | 7 | 6 | 30 | 61 | 60 | 62 | 64 |
| **Route 2** | Arrival time | 45.37 | 32.87 | 46.57 | 35.42 | 25.57 | 51.84 | 22.72 | 64.68 | 41.99 | 58.67 | 55.84 | 65.21 | 59 | 70.64 | 69.58 | 63.69 | 66.16 | 70.38 |
| | Vehicle load | 10 | 25 | 34 | 43 | 59 | 70 | 81 | 95 | 105 | 114 | 126 | 139 | 149 | 159 | 169 | 177 | 188 | 200 |
| | Nodes | 39 | 77 | 25 | 44 | 43 | 18 | 24 | 27 | 28 | 29 | 45 | 19 | 20 | 21 | 22 | | |
| **Route 3** | Arrival time | 39.44 | 82.62 | 65.07 | 63.85 | 23.38 | 51.84 | 73.96 | 85.14 | 67.37 | 69.67 | 61.28 | 64.72 | 78.27 | 79.1 | 80.88 | | |
| | Vehicle load | 12 | 22 | 33 | 42 | 57 | 69 | 80 | 89 | 97 | 109 | 125 | 138 | 154 | 167 | 180 | | |
| | Nodes | 47 | 68 | 54 | 67 | 66 | 49 | 48 | 53 | 40 | 79 | 55 | 56 | 58 | 57 | 59 | 23 | |
| **Route 4** | Arrival time | 48.99 | 31.77 | 49.12 | 35.04 | 72.45 | 47.65 | 25.63 | 43.96 | 55.69 | 74.08 | 27.8 | 54.95 | 61.87 | 57.17 | 60.5 | 82.93 | |
| | Vehicle load | 13 | 24 | 37 | 48 | 59 | 71 | 85 | 99 | 107 | 120 | 133 | 145 | 160 | 173 | 186 | 200 | |
| | Nodes | 75 | 42 | 70 | 69 | 71 | 38 | 3 | 2 | 36 | 31 | 32 | 33 | 80 | 35 | 63 | 65 | |
| **Route 5** | Arrival time | 36.39 | 69.78 | 31.51 | 26.38 | 30.73 | 28.35 | 49.98 | 0 | 64.56 | 65.21 | 54.32 | 56.95 | 51.37 | 59.63 | 74.38 | 77.66 | |
| | Vehicle load | 11 | 25 | 35 | 48 | 59 | 72 | 85 | 94 | 107 | 118 | 130 | 142 | 155 | 170 | 180 | 198 | |

Table 8. Routing detail of Group 3 (Green).

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 26 | 25 | 20 | 21 | 19 | 66 | 65 | 47 | 13 | 14 | 16 | 17 | 3 | 15 |
| **Route 1** | Arrival time | 19.27 | 21.04 | 25.14 | 27.32 | 30.45 | 33.57 | 34.69 | 40.72 | 46.47 | 49.85 | 62.85 | 68.03 | 83.08 | 93.16 |
| | Vehicle load | 12 | 23 | 39 | 52 | 65 | 76 | 94 | 107 | 117 | 129 | 140 | 151 | 164 | 179 |
| | Nodes | 44 | 43 | 42 | 40 | 39 | 38 | 32 | 36 | 33 | 34 | 37 | 35 | 31 | 30 |
| **Route 2** | Arrival time | 20.33 | 24.98 | 30.25 | 37.08 | 38.88 | 41.26 | 44.86 | 49.56 | 52.33 | 53.43 | 56.36 | 56.78 | 60.51 | 73.75 |
| | Vehicle load | 9 | 24 | 38 | 46 | 58 | 71 | 83 | 96 | 108 | 119 | 128 | 143 | 154 | 164 |
| | Nodes | 52 | 51 | 49 | 50 | 41 | | | | | | | | | |
| **Route 3** | Arrival time | 53.49 | 62.72 | 68.55 | 78.43 | 88.43 | | | | | | | | | |
| | Vehicle load | 11 | 24 | 36 | 48 | 62 | | | | | | | | | |
| | Nodes | 53 | 54 | 57 | 55 | 56 | 18 | 48 | 28 | | | | | | |
| **Route 4** | Arrival time | 29.65 | 39.15 | 44.6 | 48.45 | 50.57 | 68 | 74.55 | 84.28 | | | | | | |
| | Vehicle load | 14 | 27 | 40 | 53 | 65 | 77 | 91 | 99 | | | | | | |
| | Nodes | 61 | 46 | 60 | 59 | 58 | 24 | 22 | 23 | | | | | | |
| **Route 5** | Arrival time | 17.78 | 44.33 | 48.8 | 54.47 | 56.77 | 65.65 | 69.48 | 73.96 | | | | | | |
| | Vehicle load | 10 | 24 | 32 | 45 | 60 | 71 | 84 | 98 | | | | | | |
| | Nodes | 68 | 71 | 72 | 69 | 70 | 11 | 12 | 7 | 6 | 10 | 8 | 9 | 62 | |
| **Route 6** | Arrival time | 44.15 | 51.85 | 53.78 | 57.38 | 61.31 | 64.24 | 67.42 | 72.3 | 73.4 | 78.4 | 80.63 | 84.11 | 91.51 | |
| | Vehicle load | 11 | 22 | 35 | 48 | 58 | 74 | 83 | 96 | 106 | 121 | 135 | 147 | 158 | |
| | Nodes | 74 | 63 | 64 | 75 | 73 | 29 | 45 | 67 | 2 | 4 | 5 | 27 | | |
| **Route 7** | Arrival time | 14.61 | 16.81 | 18.01 | 21.44 | 25.16 | 32.83 | 41.75 | 50.87 | 65.27 | 69.97 | 72.62 | 74.17 | | |
| | Vehicle load | 13 | 23 | 35 | 46 | 58 | 70 | 86 | 97 | 106 | 116 | 125 | 134 | | |

Table 9. Routing detail of Group 4 (Blue).

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 12 | 14 | 27 | 66 | 68 | 22 | 62 | 63 | 61 | 64 | 65 | 67 | | | | | |
| **Route 1** | Arrival time | 16.84 | 18.72 | 36.62 | 49.07 | 49.07 | 63.35 | 71.02 | 71.02 | 72.45 | 72.45 | 72.45 | 84.41 | | | | | |
| | Vehicle load | 9 | 21 | 30 | 41 | 52 | 65 | 76 | 86 | 96 | 108 | 126 | 137 | | | | | |
| | Nodes | 21 | 18 | 19 | 16 | 17 | 2 | | | | | | | | | | | |
| **Route 2** | Arrival time | 35.54 | 41.22 | 41.22 | 54.8 | 73.64 | 100.41 | | | | | | | | | | | |
| | Vehicle load | 13 | 25 | 38 | 49 | 60 | 69 | | | | | | | | | | | |
| | Nodes | 43 | 50 | 45 | 53 | 46 | 47 | 51 | 48 | 49 | 52 | 15 | 25 | 6 | 23 | 24 | | |
| **Route 3** | Arrival time | 11.1 | 23.26 | 24.69 | 28.27 | 31.1 | 35.15 | 36.53 | 40.96 | 40.96 | 43.54 | 53.04 | 66.34 | 58.88 | 73.89 | 75.99 | | |
| | Vehicle load | 15 | 27 | 43 | 57 | 71 | 84 | 97 | 111 | 123 | 134 | 149 | 160 | 139 | 186 | 197 | | |
| | Nodes | 56 | 55 | 44 | 11 | 8 | 10 | 9 | 38 | 42 | 31 | 6 | 3 | 4 | 5 | | | |
| **Route 4** | Arrival time | 10.99 | 21.69 | 25.19 | 35.44 | 35.44 | 36.99 | 38.67 | 45.44 | 47.11 | 50.56 | 58.88 | 60.85 | 69.75 | 72.62 | | | |
| | Vehicle load | 12 | 25 | 34 | 50 | 64 | 79 | 91 | 104 | 118 | 129 | 139 | 152 | 162 | 171 | | | |
| | Nodes | 57 | 70 | 69 | 71 | 35 | 20 | 54 | 13 | | | | | | | | | |
| **Route 5** | Arrival time | 9.36 | 12.53 | 19.32 | 22.82 | 32.59 | 53.54 | 60.57 | 82.8 | | | | | | | | | |
| | Vehicle load | 13 | 23 | 36 | 47 | 62 | 78 | 91 | 101 | | | | | | | | | |
| | Nodes | 59 | 58 | 40 | 39 | 60 | 37 | 36 | 30 | 73 | 29 | 28 | 72 | 34 | 32 | 33 | 7 | 41 |
| **Route 6** | Arrival time | 17.1 | 17.1 | 20.17 | 21.15 | 24.88 | 27.95 | 45.74 | 48.36 | 49.64 | 51.46 | 52.76 | 54.68 | 59.63 | 62.75 | 65.55 | 68.15 | 79.57 |
| | Vehicle load | 13 | 28 | 36 | 48 | 56 | 65 | 78 | 88 | 100 | 112 | 120 | 133 | 144 | 156 | 168 | 181 | 195 |

Table 10. Routing detail of Group 5 (Red).

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 15 | 5 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 6 | 7 | | | | | | |
| **Route 1** | Arrival time | 15.92 | 26.2 | 32.32 | 33.99 | 38.02 | 41.54 | 43.77 | 47.14 | 52.79 | 68.84 | 75.84 | | | | | | |
| | Vehicle load | 15 | 24 | 38 | 50 | 65 | 81 | 90 | 100 | 112 | 122 | 135 | | | | | | |
| | Nodes | 23 | 24 | 41 | 68 | 69 | 18 | 17 | 42 | 16 | 44 | 43 | 3 | 2 | 4 | | | |
| **Route 2** | Arrival time | 10.73 | 24.58 | 27.8 | 28.82 | 31.05 | 35.92 | 36.9 | 41.1 | 46.63 | 63.18 | 64.95 | 72.81 | 77.96 | 84.21 | | | |
| | Vehicle load | 14 | 25 | 39 | 50 | 63 | 75 | 86 | 100 | 111 | 120 | 135 | 148 | 157 | 167 | | | |
| | Nodes | 29 | 28 | 30 | 62 | 21 | 61 | 55 | 56 | 54 | 59 | 58 | 57 | 27 | 25 | 60 | 31 | 26 |
| **Route 3** | Arrival time | 23.7 | 23.7 | 25.55 | 31.35 | 34.87 | 35.64 | 40.54 | 42.92 | 45.24 | 47.82 | 51.94 | 52.72 | 56.57 | 61.14 | 65.17 | 69.39 | 71.19 |
| | Vehicle load | 12 | 20 | 30 | 41 | 54 | 64 | 77 | 89 | 102 | 115 | 130 | 143 | 152 | 163 | 171 | 182 | 194 |
| | Nodes | 32 | 37 | 70 | 35 | 36 | 34 | 33 | 20 | 19 | 66 | 67 | 65 | 63 | 64 | | | |
| **Route 4** | Arrival time | 12.4 | 18.48 | 23.85 | 27.78 | 49.07 | 54.45 | 60.52 | 64.95 | 66.38 | 67.58 | 70.53 | 72.45 | 76.01 | 77.66 | | | |
| | Vehicle load | 12 | 21 | 31 | 46 | 59 | 70 | 82 | 98 | 111 | 122 | 133 | 151 | 161 | 173 | | | |
| | Nodes | 48 | 49 | 51 | 45 | 50 | 22 | 71 | 46 | 47 | 38 | 40 | 39 | 52 | 53 | | | |
| **Route 5** | Arrival time | 6.43 | 10.28 | 14 | 17.17 | 19.87 | 23.7 | 29.08 | 33.91 | 37.26 | 65.29 | 68.27 | 74.17 | 75.54 | 83.44 | | | |
| | Vehicle load | 14 | 26 | 39 | 55 | 67 | 80 | 91 | 105 | 118 | 131 | 139 | 151 | 162 | 176 | | | |

Table 11. Routing detail of Group 6 (Purple).

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 1 | 156 | 105 | 108 | 390 | 389 | 154 | 387 | 153 | 388 | 386 | 157 | 151 | 192 | 167 | 144 |
| **Route 1** | Arrival time | 2.4 | 17.5 | 25.28 | 26.5 | 34.5 | 34.87 | 36.57 | 37.54 | 37.87 | 37.87 | 38.32 | 40.45 | 45.43 | 47.51 | 47.99 | 50.86 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 306 | 280 | 318 | 319 | 180 | 181 | 182 | 183 | 175 | 176 | 178 | | | | | |
| **Route 2** | Arrival time | 7.8 | 11.88 | 13.25 | 21.15 | 44.65 | 46.75 | 51.22 | 56.89 | 72.47 | 72.47 | 78.05 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 279 | 317 | 311 | 316 | 315 | 91 | 372 | 375 | 370 | 374 | 373 | | | | | |
| **Route 3** | Arrival time | 9.08 | 15.31 | 18.48 | 21.18 | 24.38 | 29.56 | 37.09 | 39.57 | 43.44 | 46.69 | 47.47 | 51.32 | 64.39 | 65.41 | 68.59 | 71.77 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 320 | 325 | 326 | 329 | 330 | 323 | 327 | 322 | 321 | 332 | 324 | 328 | 399 | 400 | 398 | 401 |
| **Route 4** | Arrival time | 9.65 | 22.45 | 22.45 | 25.03 | 28.6 | 31.43 | 34.18 | 35.61 | 38.53 | 42.03 | 47.25 | 48.63 | 71.05 | 71.05 | 72.48 | 72.48 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 348 | 406 | 263 | 262 | 261 | 356 | 445 | 444 | 190 | 189 | 131 | 132 | 283 | 142 | 140 | 141 |
| **Route 5** | Arrival time | 5.75 | 8.17 | 10.4 | 14.15 | 15.13 | 18.86 | 22.48 | 24.9 | 41.62 | 44.19 | 45.97 | 46.42 | 47.34 | 51.54 | 52.22 | 53.45 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 314 | 312 | 313 | 449 | 371 | 90 | 377 | 93 | 307 | 384 | 28 | 450 | 396 | | | |
| **Route 6** | Arrival time | 6.43 | 9.15 | 12.5 | 22.3 | 29.82 | 35.95 | 36.72 | 42.52 | 45.74 | 46.76 | 54.53 | 76.75 | 78.42 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | | | |
| | Nodes | 407 | 4 | 2 | 5 | 3 | 253 | 6 | 255 | 254 | 256 | 251 | 250 | 257 | 128 | 158 | 159 |
| **Route 7** | Arrival time | 6.52 | 11.22 | 15.09 | 17.06 | 19.39 | 27.47 | 33.25 | 36.8 | 38.72 | 41.4 | 47.82 | 49.12 | 50.57 | 73.72 | 73.72 | 74.85 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 408 | 259 | 252 | 260 | 264 | 9 | 8 | 7 | 10 | 210 | 207 | 206 | 204 | 202 | 200 | 201 |
| **Route 8** | Arrival time | 7.07 | 13.44 | 16.24 | 18.84 | 20.51 | 28.78 | 30.46 | 32.53 | 32.53 | 45.25 | 55.12 | 56.92 | 60 | 60.42 | 63.22 | 64.32 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 408 | 13 | 335 | 334 | 336 | 337 | | | | | | | | | | |
| **Route 9** | Arrival time | 7.33 | 9.21 | 43.68 | 52.96 | 59.11 | 70.13 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 408 | 89 | 104 | 155 | 391 | 107 | 119 | 152 | | | | | | | | |
| **Route 10** | Arrival time | 7.73 | 46.15 | 63.37 | 66.49 | 69.22 | 70.87 | 76.95 | 79.13 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |
| | Nodes | 349 | 350 | 258 | 289 | 185 | 187 | 188 | 160 | 161 | 440 | 364 | 284 | 285 | 282 | 143 | 169 |
| **Route 11** | Arrival time | 7.67 | 7.67 | 13.57 | 36.6 | 39.68 | 43.08 | 46 | 47.57 | 49.92 | 52.52 | 55.59 | 61.07 | 61.07 | 62.19 | 67.07 | 68.67 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 94 | 87 | 382 | 383 | 381 | 88 | 379 | 380 | 378 | 309 | 310 | 24 | 23 | 22 | 21 | 25 |
| **Route 12** | Arrival time | 9.33 | 15.21 | 16.41 | 19.36 | 21.28 | 23.75 | 26.85 | 28.5 | 32.73 | 40.91 | 42.68 | 54.05 | 56.28 | 59.8 | 63.88 | 65.51 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 376 | 95 | 265 | 81 | 423 | 305 | 303 | 302 | 301 | 304 | 299 | 294 | 230 | 295 | 274 | 436 |
| **Route 13** | Arrival time | 9.42 | 11.52 | 15.24 | 28.01 | 37.49 | 41.94 | 44.76 | 48.31 | 51.23 | 55.26 | 59.84 | 61.57 | 62.69 | 65.06 | 68.79 | 68.79 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 97 | 98 | 99 | 149 | 148 | 146 | 150 | 168 | 70 | 145 | 136 | 133 | 134 | 135 | 286 | 287 |
| **Route 14** | Arrival time | 9.65 | 9.65 | 11.5 | 36.58 | 40.16 | 41.58 | 49.85 | 55.27 | 59.07 | 61.15 | 65.25 | 67.37 | 67.37 | 67.37 | 72.45 | 73.78 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 92 | 14 | 16 | 20 | 17 | 26 | 27 | 15 | 19 | 18 | | | | | | |
| **Route 15** | Arrival time | 10.73 | 19.65 | 25.9 | 32.22 | 35.09 | 45.44 | 51.94 | 58.82 | 65.2 | 72.38 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | | |
| | Nodes | 267 | 269 | 270 | 297 | 292 | 424 | 300 | 447 | 166 | 193 | 165 | 288 | 194 | 162 | 177 | |
| **Route 16** | Arrival time | 10.95 | 15.87 | 18.59 | 29.84 | 36.52 | 39.09 | 40.51 | 49.04 | 49.94 | 53.92 | 56.65 | 61.37 | 64.39 | 70.56 | 76.04 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | |
| | Nodes | 266 | 268 | 298 | 293 | 296 | 439 | 430 | 428 | 425 | 427 | 68 | 63 | 429 | 65 | 67 | 69 |
| **Route 17** | Arrival time | 12.4 | 19.75 | 33.75 | 36.72 | 41.7 | 47.98 | 48.95 | 52.18 | 54.18 | 55.83 | 57.6 | 61.15 | 62.45 | 64.95 | 66.83 | 67.43 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 271 | 73 | 79 | 277 | 433 | 80 | 426 | 412 | 421 | 422 | 127 | 126 | 129 | 123 | 122 | 121 |
| **Route 18** | Arrival time | 12.43 | 20.38 | 20.73 | 24.11 | 26.93 | 27.15 | 36.55 | 39.43 | 40.43 | 45.96 | 57.69 | 59.51 | 59.51 | 59.71 | 60.64 | 61.34 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 420 | 353 | 58 | 59 | 139 | 60 | 354 | 36 | 31 | 32 | 62 | 61 | 71 | 72 | 66 | 448 |
| **Route 19** | Arrival time | 12.88 | 15.28 | 18.98 | 18.98 | 18.98 | 19.51 | 20.98 | 23.06 | 26.61 | 26.94 | 28.87 | 32.49 | 36.12 | 36.12 | 43.44 | 43.94 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 418 | 355 | 351 | 352 | 437 | 419 | 33 | 232 | 29 | 409 | 281 | 331 | | | | |
| **Route 20** | Arrival time | 14.75 | 19.45 | 24.13 | 26.76 | 30.04 | 33.76 | 41.94 | 48.49 | 50.51 | 56.16 | 65.84 | 74.56 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 40 | 39 | 41 | 42 | 43 | 37 | 38 | 416 | 417 | 414 | 415 | 413 | 12 | 48 | 45 | 47 |
| **Route 21** | Arrival time | 15.3 | 18.78 | 21.23 | 26.43 | 29.61 | 30.49 | 31.11 | 39.43 | 41.36 | 44.96 | 48.89 | 57.27 | 67.3 | 73.83 | 77.26 | 79.03 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 35 | 227 | 228 | 438 | 229 | 231 | 224 | 44 | 243 | 46 | 34 | 170 | 137 | | | |
| **Route 22** | Arrival time | 15.75 | 22.3 | 24.93 | 26.9 | 29.8 | 33.43 | 36.45 | 45.1 | 54.48 | 58.1 | 70.05 | 73.15 | 77.42 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | | | |
| | Nodes | 347 | 344 | 343 | 195 | 233 | 340 | 341 | 342 | 339 | | | | | | | |
| **Route 23** | Arrival time | 15.72 | 29.42 | 31.72 | 39.87 | 48.67 | 63.52 | 65.64 | 71.39 | 79.87 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | | |
| | Nodes | 347 | 431 | 276 | 147 | 120 | 446 | 130 | 111 | 109 | 113 | 103 | 106 | 117 | 163 | | |
| **Route 24** | Arrival time | 15.92 | 20.65 | 23.38 | 29.06 | 37.74 | 38.72 | 41.72 | 45.49 | 48.44 | 53.01 | 57.01 | 63.23 | 70.15 | 75.65 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | | |
| | Nodes | 435 | 434 | 275 | 278 | 82 | 83 | 84 | 291 | 74 | 75 | 76 | 77 | 78 | 30 | 234 | 124 |
| **Route 25** | Arrival time | 15.92 | 19.3 | 26.68 | 30.8 | 34.93 | 37.23 | 38.2 | 40.9 | 45.83 | 46.66 | 48.44 | 50.49 | 53.91 | 59.91 | 62.61 | 74.59 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |

Table 12. Routing detail of Instance 1. Part 1.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 172 | 184 | 403 | 405 | 179 | 402 | 404 | | | | | | | | | |
| **Route 26** | Arrival time | 15.98 | 27.91 | 40.36 | 40.36 | 54.64 | 63.74 | 63.74 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 272 | 273 | 235 | 196 | 226 | 223 | 215 | 248 | 247 | 241 | 361 | 222 | 218 | 220 | 363 | 362 |
| **Route 27** | Arrival time | 16.2 | 17.38 | 22.96 | 29.24 | 35.16 | 44.54 | 50.07 | 51.39 | 53.56 | 55.96 | 57.49 | 64.04 | 67.81 | 67.81 | 72.68 | 73.46 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 211 | 208 | 205 | 199 | 203 | 198 | 197 | 338 | | | | | | | | |
| **Route 28** | Arrival time | 16.63 | 30.18 | 41.36 | 44.96 | 49.66 | 54.16 | 56.64 | 74.74 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |
| | Nodes | 56 | 411 | 410 | 52 | 219 | 238 | 221 | 290 | 239 | 214 | 242 | 244 | 367 | 249 | 365 | 237 |
| **Route 29** | Arrival time | 16.98 | 21.81 | 22.93 | 28.48 | 40.41 | 40.41 | 45.16 | 49.24 | 52.36 | 58.78 | 67.93 | 70.11 | 74.19 | 74.49 | 76.39 | 78.31 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 346 | 225 | 345 | 53 | 138 | 171 | 191 | 164 | 369 | 368 | 441 | 366 | | | | |
| **Route 30** | Arrival time | 17.78 | 20.45 | 24.92 | 34.37 | 48.99 | 54.56 | 62.49 | 66.14 | 69.69 | 72.56 | 75.63 | 78 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 57 | 55 | 51 | 50 | 186 | 240 | 442 | 216 | 217 | 245 | 246 | 213 | 360 | 212 | | |
| **Route 31** | Arrival time | 19.27 | 23.45 | 28.5 | 33.1 | 49.9 | 56.15 | 63 | 65.68 | 65.68 | 70.65 | 71.58 | 73.66 | 74.91 | 79.58 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | | |
| | Nodes | 54 | 49 | 209 | 359 | 357 | 443 | 236 | | | | | | | | | |
| **Route 32** | Arrival time | 19.33 | 27.03 | 43.13 | 67.75 | 70.53 | 72.96 | 75.51 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 394 | 116 | 115 | 118 | 100 | 101 | 102 | 112 | 392 | 110 | 395 | 393 | | | | |
| **Route 33** | Arrival time | 20.27 | 24.42 | 26.47 | 27.77 | 32.24 | 38.77 | 38.77 | 42.84 | 46.52 | 55.79 | 62.07 | 67.44 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 114 | 397 | 64 | | | | | | | | | | | | | |
| **Route 34** | Arrival time | 22.47 | 46.07 | 70.17 | | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | | | | | |
| | Nodes | 358 | 125 | | | | | | | | | | | | | | |
| **Route 35** | Arrival time | 22.47 | 43.55 | | | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | | | | | | | | | | | | | | |
| | Nodes | 174 | 173 | | | | | | | | | | | | | | |
| **Route 36** | Arrival time | 25.52 | 33.45 | | | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | | | | | | | | | | | | | | |

Table 13. Routing detail of Instance 1. Part 2.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 1 | 156 | 105 | 108 | 107 | | | | | | | | | | | |
| **Route 1** | Arrival time | 25 | 40.1 | 47.88 | 49.1 | 54.68 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 306 | 280 | 318 | 319 | 184 | | | | | | | | | | | |
| **Route 2** | Arrival time | 25 | 29.08 | 30.45 | 38.35 | 54.9 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 279 | 317 | 311 | 316 | 315 | 91 | 372 | | | | | | | | | |
| **Route 3** | Arrival time | 25 | 31.23 | 34.4 | 37.1 | 40.3 | 45.48 | 53.01 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 320 | 325 | 326 | 329 | 330 | 323 | 327 | 322 | 321 | | | | | | | |
| **Route 4** | Arrival time | 25 | 37.8 | 37.8 | 40.38 | 43.95 | 46.78 | 49.53 | 50.96 | 53.88 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | | |
| | Nodes | 348 | 406 | 263 | 262 | 261 | 356 | 445 | 444 | 250 | 251 | 257 | 258 | 252 | | | |
| **Route 5** | Arrival time | 25 | 27.42 | 29.65 | 33.4 | 34.38 | 38.11 | 41.73 | 44.15 | 46.07 | 47.35 | 48.47 | 51.32 | 53.94 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | | | |
| | Nodes | 314 | 312 | 313 | 449 | 371 | 375 | | | | | | | | | | |
| **Route 6** | Arrival time | 25 | 27.72 | 31.07 | 40.87 | 48.39 | 53.26 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 407 | 190 | 189 | | | | | | | | | | | | | |
| **Route 7** | Arrival time | 25 | 50.93 | 53.5 | | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | | | | | |
| | Nodes | 408 | 259 | 255 | 254 | 256 | 6 | 260 | | | | | | | | | |
| **Route 8** | Arrival time | 25 | 31.37 | 39.44 | 41.36 | 44.04 | 49.46 | 54.44 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 11 | 13 | 8 | 9 | 7 | 10 | 210 | | | | | | | | | |
| **Route 9** | Arrival time | 25 | 26.88 | 35.16 | 36.84 | 38.41 | 38.41 | 51.13 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 333 | 324 | 328 | 332 | | | | | | | | | | | | |
| **Route 10** | Arrival time | 25 | 37.08 | 38.46 | 44.99 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | | | |
| | Nodes | 349 | 350 | 128 | 158 | 159 | | | | | | | | | | | |
| **Route 11** | Arrival time | 25 | 25 | 52.15 | 52.15 | 53.28 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 3 | 2 | 5 | 253 | 264 | 418 | | | | | | | | | | |
| **Route 12** | Arrival time | 25 | 25.65 | 27.62 | 35.75 | 41.13 | 53.01 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 4 | 42 | 43 | 37 | 38 | 41 | | | | | | | | | | |
| **Route 13** | Arrival time | 25 | 42.55 | 45.73 | 46.61 | 47.23 | 53.33 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 94 | 85 | 86 | 308 | 385 | 384 | 307 | 93 | | | | | | | | |
| **Route 14** | Arrival time | 25 | 35.02 | 36.04 | 39.22 | 42.4 | 45.38 | 49.06 | 54.91 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |
| | Nodes | 376 | 95 | 265 | 450 | 396 | | | | | | | | | | | |
| **Route 15** | Arrival time | 25 | 27.1 | 30.82 | 52.05 | 53.72 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 97 | 98 | 99 | 90 | 377 | 378 | 379 | 380 | 88 | 87 | 382 | 383 | | | | |
| **Route 16** | Arrival time | 25 | 25 | 26.85 | 32.42 | 33.19 | 38.62 | 42.5 | 44.15 | 47.7 | 49.13 | 50.33 | 53.28 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 96 | 374 | 373 | 370 | 81 | 277 | | | | | | | | | | |
| **Route 17** | Arrival time | 25 | 30.48 | 31.26 | 34.91 | 52.93 | 54.38 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 92 | 14 | 16 | 24 | 23 | | | | | | | | | | | |
| **Route 18** | Arrival time | 25 | 33.92 | 40.17 | 50.52 | 52.75 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 267 | 269 | 270 | 297 | 292 | 230 | 295 | | | | | | | | | |
| **Route 19** | Arrival time | 25 | 29.92 | 32.64 | 43.89 | 50.57 | 51.8 | 54.17 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 381 | 268 | 298 | 274 | 436 | 424 | | | | | | | | | | |
| **Route 20** | Arrival time | 25 | 32.63 | 46.63 | 51.8 | 51.8 | 54.68 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 266 | 390 | 389 | 154 | | | | | | | | | | | | |
| **Route 21** | Arrival time | 25 | 52.65 | 53.02 | 54.72 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | | | |
| | Nodes | 271 | 68 | 439 | 430 | 428 | 425 | 427 | 426 | | | | | | | | |
| **Route 22** | Arrival time | 25 | 39.55 | 42.1 | 43.07 | 46.3 | 48.3 | 49.95 | 53.83 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |
| | Nodes | 310 | 309 | 20 | 21 | 22 | 25 | 17 | | | | | | | | | |
| **Route 23** | Arrival time | 25 | 26.77 | 35.85 | 37.52 | 41.55 | 46.87 | 51.32 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 420 | 353 | 58 | 59 | 139 | 60 | 354 | 36 | 31 | 32 | 62 | 61 | 71 | 72 | 84 | 83 |
| **Route 24** | Arrival time | 25 | 27.4 | 31.1 | 31.1 | 31.1 | 31.63 | 33.1 | 35.18 | 38.73 | 39.06 | 40.99 | 44.61 | 48.24 | 48.24 | 53.97 | 54.94 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 15 | 26 | 27 | 28 | | | | | | | | | | | | |
| **Route 25** | Arrival time | 25 | 33.07 | 39.57 | 47.6 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | | | |

Table 14. Routing detail of Instance 2. Part 1.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 19 | 18 | 118 | | | | | | | | | |
| **Route 26** | Arrival time | 25 | 32.18 | 54.98 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | |
| | Nodes | 419 | 437 | 352 | 351 | 355 | 75 | 76 | 77 | | | | |
| **Route 27** | Arrival time | 25 | 29.07 | 31.92 | 34.55 | 39.35 | 48.55 | 50.33 | 52.38 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | |
| | Nodes | 40 | 39 | 415 | 417 | 416 | 414 | 413 | | | | | |
| **Route 28** | Arrival time | 25 | 28.48 | 33.33 | 37.31 | 39.39 | 42.74 | 48.79 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 35 | 33 | 232 | 29 | 63 | 429 | 65 | 67 | 69 | 66 | 448 | 291 |
| **Route 29** | Arrival time | 25 | 29.7 | 36.25 | 38.27 | 43.69 | 44.99 | 47.49 | 49.37 | 49.97 | 50.07 | 50.57 | 54.47 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 |
| | Nodes | 347 | 89 | | | | | | | | | | |
| **Route 30** | Arrival time | 25 | 54.25 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | | | | | | | | | | |
| | Nodes | 432 | 423 | 305 | 303 | 302 | 301 | 304 | | | | | |
| **Route 31** | Arrival time | 25 | 37.02 | 41.47 | 44.29 | 47.84 | 50.76 | 54.79 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 435 | 434 | 433 | 80 | 73 | 79 | 82 | 422 | 299 | 294 | | |
| **Route 32** | Arrival time | 25 | 28.38 | 32.16 | 32.38 | 33.78 | 34.13 | 36.43 | 46.01 | 50.33 | 52.06 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | |
| | Nodes | 172 | 182 | 180 | 181 | 183 | | | | | | | |
| **Route 33** | Arrival time | 25 | 38.3 | 42.07 | 44.17 | 49.62 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | |
| | Nodes | 272 | 273 | 275 | 296 | 300 | | | | | | | |
| **Route 34** | Arrival time | 25 | 26.18 | 34.43 | 42.8 | 50.12 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | |
| | Nodes | 211 | 207 | 206 | 204 | 202 | 200 | 201 | 199 | 205 | | | |
| **Route 35** | Arrival time | 25 | 36.97 | 38.77 | 41.85 | 42.27 | 45.07 | 46.17 | 50.09 | 53.69 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | |
| | Nodes | 56 | 411 | 48 | 45 | 47 | 44 | 243 | | | | | |
| **Route 36** | Arrival time | 25 | 29.83 | 32.33 | 35.76 | 37.53 | 44.55 | 53.93 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 78 | 30 | 234 | 421 | 412 | 409 | 164 | | | | | |
| **Route 37** | Arrival time | 25 | 31 | 33.7 | 40.13 | 43.58 | 46.98 | 54.43 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 278 | 276 | 149 | 148 | 146 | 150 | | | | | | |
| **Route 38** | Arrival time | 25 | 31.05 | 41.25 | 44.83 | 46.25 | 54.52 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | |
| | Nodes | 235 | 227 | 228 | 438 | 229 | 231 | 224 | 12 | | | | |
| **Route 39** | Arrival time | 25 | 27.95 | 30.58 | 32.55 | 35.45 | 39.08 | 42.1 | 52.57 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | |
| | Nodes | 346 | 225 | 345 | 344 | 343 | 195 | 54 | | | | | |
| **Route 40** | Arrival time | 25 | 27.67 | 32.14 | 37.81 | 40.11 | 48.26 | 53.18 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 196 | 226 | 223 | 46 | 410 | | | | | | | |
| **Route 41** | Arrival time | 25 | 30.92 | 40.3 | 47.45 | 54.15 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | |
| | Nodes | 74 | 431 | 152 | 119 | | | | | | | | |
| **Route 42** | Arrival time | 25 | 36.2 | 50.45 | 52.35 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | |
| | Nodes | 57 | 55 | 53 | 52 | 145 | 70 | 138 | 140 | | | | |
| **Route 43** | Arrival time | 25 | 29.18 | 33.01 | 38.01 | 51.53 | 51.7 | 53.68 | 54.65 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | |
| | Nodes | 394 | 116 | 115 | 100 | 106 | 391 | 155 | | | | | |
| **Route 44** | Arrival time | 25 | 29.15 | 31.2 | 35.25 | 45.12 | 49.24 | 52.26 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 403 | 405 | 179 | 399 | 400 | 398 | 401 | 402 | 404 | | | |
| **Route 45** | Arrival time | 25 | 25 | 39.28 | 46.95 | 46.95 | 48.38 | 48.38 | 48.38 | 48.38 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | |
| | Nodes | 197 | 203 | 334 | 335 | | | | | | | | |
| **Route 46** | Arrival time | 25 | 31.02 | 41.57 | 51.45 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | |
| | Nodes | 51 | 50 | 214 | | | | | | | | | |
| **Route 47** | Arrival time | 25 | 29.6 | 49.23 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | |
| | Nodes | 209 | 208 | 336 | | | | | | | | | |
| **Route 48** | Arrival time | 25 | 39.4 | 54 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | |
| | Nodes | 368 | 369 | 161 | 440 | 364 | 185 | 187 | 188 | 160 | | | |
| **Route 49** | Arrival time | 25 | 27.87 | 35.55 | 38.15 | 41.22 | 43.92 | 47.32 | 50.24 | 51.81 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | |
| | Nodes | 49 | 233 | 340 | 341 | 342 | | | | | | | |
| **Route 50** | Arrival time | 25 | 31.55 | 46.4 | 48.52 | 54.27 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | |

Table 15. Routing detail of Instance 2. Part 2.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 236 | 248 | 247 | 241 | 361 | 222 | 218 | 220 | 363 | 362 | 186 | | | |
| **Route 51** | Arrival time | 25 | 28.98 | 31.15 | 33.55 | 35.08 | 41.63 | 45.4 | 45.4 | 50.27 | 51.05 | 54.23 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | |
| | Nodes | 395 | 110 | 130 | 446 | 120 | 121 | 122 | 126 | 129 | 127 | 123 | 124 | | |
| **Route 52** | Arrival time | 25 | 32.93 | 37.96 | 41.58 | 42.56 | 44.34 | 45.04 | 46.06 | 46.06 | 47.86 | 49.86 | 52.69 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | |
| | Nodes | 114 | 111 | 109 | 387 | 153 | 388 | 386 | | | | | | | |
| **Route 53** | Arrival time | 25 | 41.87 | 44.82 | 53.35 | 53.68 | 53.68 | 54.13 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | |
| | Nodes | 358 | 359 | 215 | 249 | 365 | 237 | 442 | 216 | 217 | 284 | 285 | 282 | 143 | 169 |
| **Route 54** | Arrival time | 25 | 25.28 | 27.93 | 29.51 | 31.41 | 33.33 | 35.21 | 37.89 | 37.89 | 44.97 | 44.97 | 46.09 | 50.97 | 52.57 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 |
| | Nodes | 357 | 443 | 367 | 239 | 219 | 238 | 221 | 290 | 240 | | | | | |
| **Route 55** | Arrival time | 25 | 27.43 | 34.13 | 38.56 | 41.43 | 41.43 | 46.18 | 50.26 | 53.83 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | |
| | Nodes | 212 | 245 | 246 | 213 | 360 | 244 | 242 | 34 | 170 | 136 | | | | |
| **Route 56** | Arrival time | 25 | 29.47 | 30.4 | 32.48 | 33.73 | 34.96 | 36.43 | 47.5 | 50.6 | 54.73 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | |
| | Nodes | 441 | 366 | 447 | 166 | 168 | 192 | 167 | 144 | 141 | 133 | 134 | 135 | | |
| **Route 57** | Arrival time | 25 | 27.37 | 34.64 | 35.54 | 40.21 | 42.23 | 42.71 | 45.58 | 48.5 | 53.73 | 53.73 | 53.73 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | |
| | Nodes | 393 | 101 | 102 | 103 | 113 | 112 | 392 | | | | | | | |
| **Route 58** | Arrival time | 25 | 30.45 | 30.45 | 33.3 | 39.12 | 41.99 | 45.67 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | |
| | Nodes | 198 | 338 | 339 | | | | | | | | | | | |
| **Route 59** | Arrival time | 25 | 40.98 | 50.48 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | | | |
| | Nodes | 174 | 178 | 175 | 176 | | | | | | | | | | |
| **Route 60** | Arrival time | 25.52 | 44.37 | 50.05 | 50.05 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | |
| | Nodes | 125 | 157 | 151 | 193 | 165 | 194 | | | | | | | | |
| **Route 61** | Arrival time | 25.37 | 40.07 | 45.05 | 48.68 | 51.41 | 54.39 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | |
| | Nodes | 293 | 131 | 132 | 283 | 142 | 137 | 286 | 287 | | | | | | |
| **Route 62** | Arrival time | 25.63 | 36.21 | 36.66 | 37.58 | 41.78 | 45.25 | 51.97 | 53.3 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | |
| | Nodes | 147 | 331 | 171 | | | | | | | | | | | |
| **Route 63** | Arrival time | 25.82 | 42.89 | 51.46 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | | | |
| | Nodes | 173 | 337 | | | | | | | | | | | | |
| **Route 64** | Arrival time | 25 | 48.4 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | | | | | | | | | | | | |
| | Nodes | 281 | 162 | 288 | 177 | 163 | | | | | | | | | |
| **Route 65** | Arrival time | 27.83 | 29.83 | 37.73 | 42.38 | 50.75 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | |
| | Nodes | 289 | 191 | | | | | | | | | | | | |
| **Route 66** | Arrival time | 29.37 | 36.07 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | | | | | | | | | | | | |
| | Nodes | 117 | 397 | 104 | | | | | | | | | | | |
| **Route 67** | Arrival time | 29.43 | 38.4 | 48.43 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | | | |
| | Nodes | 64 | | | | | | | | | | | | | |
| **Route 68** | Arrival time | 33.07 | | | | | | | | | | | | | |
| | Vehicle load | 12 | | | | | | | | | | | | | |

Table 16. Routing detail of Instance 2. Part 3.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 1 | 156 | 105 | 108 | 390 | 389 | 154 | 387 | 153 | 388 | 386 | 157 | | | | |
| **Route 1** | Arrival time | 20 | 35.1 | 42.88 | 44.1 | 52.1 | 52.47 | 54.17 | 55.14 | 55.47 | 55.47 | 55.92 | 58.05 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 306 | 280 | 318 | 319 | 180 | 181 | | | | | | | | | | |
| **Route 2** | Arrival time | 20 | 24.08 | 25.45 | 33.35 | 56.85 | 58.95 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 279 | 317 | 311 | 316 | 315 | 91 | 372 | 375 | 370 | 374 | 373 | | | | | |
| **Route 3** | Arrival time | 20 | 26.23 | 29.4 | 32.1 | 35.3 | 40.48 | 48.01 | 50.49 | 54.36 | 57.61 | 58.39 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 320 | 325 | 326 | 329 | 330 | 323 | 327 | 322 | 321 | 332 | 324 | 328 | | | | |
| **Route 4** | Arrival time | 20 | 32.8 | 32.8 | 35.38 | 38.95 | 41.78 | 44.53 | 45.96 | 48.88 | 52.38 | 57.6 | 58.98 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 348 | 406 | 263 | 262 | 261 | 356 | 445 | 444 | 190 | 189 | | | | | | |
| **Route 5** | Arrival time | 20 | 22.42 | 24.65 | 28.4 | 29.38 | 33.11 | 36.73 | 39.15 | 55.87 | 58.44 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | | |
| | Nodes | 314 | 312 | 313 | 449 | 371 | 90 | 377 | 93 | 307 | | | | | | | |
| **Route 6** | Arrival time | 20 | 22.72 | 26.07 | 35.87 | 43.39 | 49.52 | 50.29 | 56.09 | 59.31 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | | |
| | Nodes | 407 | 4 | 2 | 5 | 3 | 253 | 6 | 255 | 254 | 256 | | | | | | |
| **Route 7** | Arrival time | 20 | 24.7 | 28.57 | 30.54 | 32.87 | 40.95 | 46.73 | 50.28 | 52.2 | 54.88 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | | |
| | Nodes | 408 | 259 | 252 | 251 | 250 | 257 | 128 | 158 | 159 | | | | | | | |
| **Route 8** | Arrival time | 20 | 26.37 | 29.17 | 32.25 | 33.55 | 35 | 58.15 | 58.15 | 59.28 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | | |
| | Nodes | 11 | 13 | 8 | 9 | 7 | 10 | 210 | 207 | 206 | | | | | | | |
| **Route 9** | Arrival time | 20 | 21.88 | 30.16 | 31.84 | 33.41 | 33.41 | 46.13 | 56 | 57.8 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | | |
| | Nodes | 333 | 183 | 182 | | | | | | | | | | | | | |
| **Route 10** | Arrival time | 20 | 46.52 | 49.82 | | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | | | | | |
| | Nodes | 349 | 350 | 258 | 89 | | | | | | | | | | | | |
| **Route 11** | Arrival time | 20 | 20 | 25.9 | 57.12 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | | | |
| | Nodes | 94 | 85 | 86 | 308 | 385 | 384 | 28 | 27 | | | | | | | | |
| **Route 12** | Arrival time | 20 | 30.02 | 31.04 | 34.22 | 37.4 | 40.38 | 48.15 | 59.05 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |
| | Nodes | 376 | 95 | 265 | 450 | 396 | 109 | | | | | | | | | | |
| **Route 13** | Arrival time | 20 | 22.1 | 25.82 | 47.05 | 48.72 | 58.7 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 97 | 98 | 99 | 378 | 379 | 380 | 88 | 87 | 382 | 383 | 381 | 269 | 270 | | | |
| **Route 14** | Arrival time | 20 | 20 | 21.85 | 27.65 | 31.53 | 33.18 | 36.73 | 38.16 | 39.36 | 42.31 | 44.23 | 52.28 | 55 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | | | |
| | Nodes | 96 | 268 | 104 | 155 | 391 | | | | | | | | | | | |
| **Route 15** | Arrival time | 20 | 31.12 | 54.09 | 57.21 | 59.94 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 92 | 14 | 16 | 24 | 23 | 22 | 21 | 25 | 20 | | | | | | | |
| **Route 16** | Arrival time | 20 | 28.92 | 35.17 | 45.52 | 47.75 | 51.27 | 55.35 | 56.98 | 58.56 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | | |
| | Nodes | 264 | 260 | 418 | 60 | 58 | 59 | 139 | 354 | 36 | 31 | 32 | 62 | 61 | 71 | 72 | 84 |
| **Route 17** | Arrival time | 20 | 21.67 | 32.4 | 36.83 | 37.36 | 37.36 | 37.36 | 38.31 | 40.39 | 43.94 | 44.27 | 46.2 | 49.82 | 53.45 | 53.45 | 59.18 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 267 | 81 | 423 | 305 | 303 | 302 | 301 | 304 | | | | | | | | |
| **Route 18** | Arrival time | 20 | 30.1 | 39.58 | 44.03 | 46.85 | 50.4 | 53.32 | 57.35 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |
| | Nodes | 266 | 149 | 148 | 146 | 151 | 150 | | | | | | | | | | |
| **Route 19** | Arrival time | 20 | 44 | 47.58 | 49 | 58.2 | 59.93 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 271 | 68 | 439 | 430 | 428 | 425 | 427 | 426 | 412 | 421 | 422 | | | | | |
| **Route 20** | Arrival time | 20 | 34.55 | 37.1 | 38.07 | 41.3 | 43.3 | 44.95 | 48.83 | 51.71 | 52.71 | 58.24 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 310 | 309 | 26 | 17 | 15 | 19 | 18 | | | | | | | | | |
| **Route 21** | Arrival time | 20 | 21.77 | 30.62 | 37.24 | 45.82 | 52.2 | 59.38 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 420 | 353 | 352 | 351 | 355 | 75 | 76 | 77 | 78 | 63 | | | | | | |
| **Route 22** | Arrival time | 20 | 22.4 | 23.6 | 26.23 | 31.03 | 40.23 | 42.01 | 44.06 | 47.48 | 58.8 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | | |
| | Nodes | 419 | 437 | 33 | 232 | 29 | 429 | 65 | 67 | 69 | 66 | 448 | 234 | | | | |
| **Route 23** | Arrival time | 20 | 24.07 | 33.22 | 39.77 | 41.79 | 48.47 | 50.97 | 52.85 | 53.45 | 53.55 | 54.05 | 58.62 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 40 | 39 | 41 | 42 | 43 | 37 | 38 | 416 | 417 | 414 | 415 | | | | | |
| **Route 24** | Arrival time | 20 | 23.48 | 25.93 | 31.13 | 34.31 | 35.19 | 35.81 | 44.13 | 46.06 | 49.66 | 53.59 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 35 | 227 | 228 | 409 | 299 | 294 | 230 | 295 | 274 | 436 | 424 | 300 | 293 | | | |
| **Route 25** | Arrival time | 20 | 26.55 | 29.18 | 33.76 | 41.04 | 42.77 | 43.89 | 46.26 | 49.99 | 49.99 | 52.87 | 54.29 | 59.26 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | | | |

Table 17. Routing detail of Instance 2’. Part 1.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 347 | 344 | 343 | 195 | 233 | 49 | | | | | | | | | |
| **Route 26** | Arrival time | 20 | 33.7 | 36 | 44.15 | 52.95 | 59.05 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | |
| | Nodes | 432 | 431 | 276 | 296 | 292 | 152 | 119 | 127 | 126 | 129 | 123 | 122 | 121 | 120 | 446 |
| **Route 27** | Arrival time | 20 | 24.73 | 27.46 | 31.39 | 36.27 | 45.04 | 46.94 | 51.66 | 53.48 | 53.48 | 53.68 | 54.61 | 55.31 | 57.09 | 58.07 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 |
| | Nodes | 435 | 434 | 297 | 275 | 298 | 447 | 166 | 168 | 192 | 167 | | | | | |
| **Route 28** | Arrival time | 20 | 23.38 | 31.91 | 33.83 | 40.36 | 51.79 | 52.69 | 57.36 | 59.38 | 59.86 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | |
| | Nodes | 172 | 175 | 176 | 178 | | | | | | | | | | | |
| **Route 29** | Arrival time | 20 | 45.38 | 45.38 | 50.96 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | | |
| | Nodes | 272 | 79 | 277 | 73 | 82 | 83 | 291 | 74 | 273 | 433 | 80 | 278 | 235 | | |
| **Route 30** | Arrival time | 20 | 22.5 | 25.88 | 26.75 | 29.4 | 31.7 | 35.1 | 40.03 | 45.76 | 50.43 | 50.65 | 51.35 | 58.05 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | | |
| | Nodes | 211 | 335 | 334 | 336 | | | | | | | | | | | |
| **Route 31** | Arrival time | 20 | 43.27 | 52.55 | 58.7 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | | |
| | Nodes | 56 | 411 | 48 | 45 | 47 | 44 | 243 | 46 | 410 | | | | | | |
| **Route 32** | Arrival time | 20 | 24.83 | 27.33 | 30.76 | 32.53 | 39.55 | 48.93 | 52.55 | 59.25 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | |
| | Nodes | 346 | 225 | 345 | 12 | 50 | 52 | 219 | 238 | | | | | | | |
| **Route 33** | Arrival time | 20 | 22.67 | 27.14 | 37.51 | 43.68 | 46.81 | 58.74 | 58.74 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | |
| | Nodes | 196 | 226 | 223 | 215 | 248 | 247 | 241 | 361 | 222 | 218 | 220 | | | | |
| **Route 34** | Arrival time | 20 | 25.92 | 35.3 | 40.83 | 42.15 | 44.32 | 46.72 | 48.25 | 54.8 | 58.57 | 58.57 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | |
| | Nodes | 413 | 53 | 289 | 185 | 187 | 188 | 160 | 161 | | | | | | | |
| **Route 35** | Arrival time | 20 | 32.33 | 44.88 | 47.96 | 51.36 | 54.28 | 55.85 | 58.2 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | |
| | Nodes | 184 | 403 | 405 | 179 | 399 | 400 | 398 | 401 | 402 | 404 | | | | | |
| **Route 36** | Arrival time | 20 | 32.45 | 32.45 | 46.73 | 54.4 | 54.4 | 55.83 | 55.83 | 55.83 | 55.83 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | |
| | Nodes | 57 | 55 | 51 | 34 | 170 | 136 | 133 | 134 | 135 | | | | | | |
| **Route 37** | Arrival time | 20 | 24.18 | 29.23 | 48.93 | 52.03 | 56.16 | 58.28 | 58.28 | 58.28 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | |
| | Nodes | 54 | 342 | 340 | 341 | 339 | 338 | | | | | | | | | |
| **Route 38** | Arrival time | 20 | 30.75 | 34.6 | 36.72 | 45.5 | 56.18 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | |
| | Nodes | 30 | 147 | 124 | 125 | 130 | 111 | 112 | 392 | | | | | | | |
| **Route 39** | Arrival time | 20.08 | 31.36 | 37.38 | 40.98 | 47.85 | 51.62 | 52.22 | 55.9 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | |
| | Nodes | 39 | 116 | 115 | 118 | 100 | 107 | 106 | 103 | 101 | 102 | | | | | |
| **Route 40** | Arrival time | 23.48 | 24.42 | 26.47 | 27.77 | 32.24 | 45.06 | 49.64 | 55.24 | 58.67 | 58.67 | | | | | |
| | Vehicle load | 24 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | |
| | Nodes | 229 | 438 | 231 | 224 | 364 | 284 | 285 | 282 | 143 | 169 | | | | | |
| **Route 41** | Arrival time | 20.6 | 22.52 | 27.44 | 30.46 | 44.81 | 50.29 | 50.29 | 51.41 | 56.29 | 57.89 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | |
| | Nodes | 197 | 201 | 200 | 204 | 202 | 199 | 205 | 203 | 198 | | | | | | |
| **Route 42** | Arrival time | 20.72 | 29.15 | 31.23 | 35.26 | 35.68 | 37.2 | 40.8 | 47.9 | 52.4 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | |
| | Nodes | 209 | 208 | 337 | | | | | | | | | | | | |
| **Route 43** | Arrival time | 21.12 | 35.52 | 59.35 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | | | | |
| | Nodes | 368 | 369 | 164 | 440 | 162 | 131 | 132 | 283 | 142 | 140 | 141 | 70 | | | |
| **Route 44** | Arrival time | 21.88 | 24.75 | 28.32 | 34.75 | 42.65 | 49.18 | 49.63 | 50.55 | 54.75 | 55.43 | 56.66 | 59.89 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | |
| | Nodes | 236 | 237 | 442 | 216 | 217 | 239 | 290 | 240 | 214 | 212 | | | | | |
| **Route 45** | Arrival time | 22.2 | 25.75 | 27.63 | 30.31 | 30.31 | 35.74 | 40.17 | 43.74 | 51.66 | 58.59 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | |
| | Nodes | 395 | 110 | 113 | 163 | 117 | | | | | | | | | | |
| **Route 46** | Arrival time | 22.42 | 30.35 | 39.98 | 51.13 | 56.45 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | |
| | Nodes | 114 | 397 | 171 | 137 | | | | | | | | | | | |
| **Route 47** | Arrival time | 22.47 | 46.07 | 58.87 | 59.5 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | | |
| | Nodes | 358 | 359 | 367 | 249 | 365 | 362 | 363 | 221 | 331 | 287 | | | | | |
| **Route 48** | Arrival time | 22.47 | 22.75 | 28.78 | 29.08 | 30.98 | 39 | 39.8 | 44.62 | 51.22 | 57.94 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | |
| | Nodes | 357 | 443 | 245 | 246 | 213 | 360 | 244 | 242 | 138 | 145 | 144 | | | | |
| **Route 49** | Arrival time | 22.23 | 24.66 | 29.99 | 30.92 | 33 | 34.25 | 35.48 | 36.95 | 47.22 | 49.35 | 56.92 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | |
| | Nodes | 441 | 366 | 281 | 193 | 165 | 288 | 194 | 177 | | | | | | | |
| **Route 50** | Arrival time | 23.82 | 26.19 | 32.07 | 38.35 | 41.08 | 45.8 | 48.82 | 54.25 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | |

Table 18. Routing detail of Instance 2’. Part 2.

| | | | | | |
|---|---|---|---|---|---|
| **Route 51** | Nodes | 393 | 286 | 186 | 191 |
| | Arrival time | 23.95 | 42.77 | 47.67 | 54.17 |
| | Vehicle load | 12 | 24 | 36 | 48 |
| **Route 52** | Nodes | 174 | 173 | | |
| | Arrival time | 25.52 | 33.45 | | |
| | Vehicle load | 12 | 24 | | |
| **Route 53** | Nodes | 64 | | | |
| | Arrival time | 33.07 | | | |
| | Vehicle load | 12 | | | |

Table 19. Routing detail of Instance 2’. Part 3.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 33 | 190 | 189 | 131 | 132 | 283 | 142 | 140 | 141 | 168 | 192 | 167 | 144 | 70 | 145 | 136 |
| **Route 1** | Arrival time | 19.53 | 33.2 | 35.77 | 37.55 | 38 | 38.92 | 43.12 | 43.8 | 45.03 | 47.68 | 49.7 | 50.18 | 53.05 | 56.17 | 58.25 | 62.35 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 193 | 151 | 150 | 157 | 152 | 390 | 389 | 154 | 387 | 153 | 388 | 386 | 119 | 391 | 107 | 155 |
| **Route 2** | Arrival time | 32.37 | 36.64 | 38.37 | 41.2 | 45.22 | 50.2 | 50.57 | 52.27 | 53.24 | 53.57 | 53.57 | 54.02 | 58.3 | 63.27 | 64.92 | 68.3 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 86 | 85 | 308 | 156 | 105 | 108 | 106 | 103 | 101 | 102 | 113 | 109 | 127 | 126 | 129 | 123 |
| **Route 3** | Arrival time | 17.43 | 18.41 | 22.61 | 43.71 | 51.49 | 52.71 | 55.34 | 60.94 | 64.37 | 64.37 | 66.75 | 71.4 | 76.25 | 78.07 | 78.07 | 78.27 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 201 | 200 | 334 | 335 | 336 | 337 | 338 | 342 | 208 | | | | | | | |
| **Route 4** | Arrival time | 27.33 | 29.41 | 37.11 | 46.99 | 55.74 | 66.76 | 86.29 | 100.07 | 122.05 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | | |
| | Nodes | 362 | 363 | 221 | 290 | 241 | 361 | 222 | 218 | 220 | 331 | 34 | 170 | 286 | 287 | 133 | 134 |
| **Route 5** | Arrival time | 28.83 | 29.63 | 34.45 | 38.53 | 40.91 | 42.44 | 48.99 | 52.76 | 52.76 | 59.24 | 67.86 | 70.96 | 73.98 | 75.31 | 81.34 | 81.34 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 380 | 379 | 87 | 382 | 383 | 381 | 88 | 385 | 384 | 307 | 93 | 310 | 309 | 450 | 396 | 111 |
| **Route 6** | Arrival time | 12.75 | 14.4 | 18.13 | 19.33 | 22.28 | 24.2 | 26.67 | 32.02 | 35 | 38.68 | 44.53 | 50.06 | 51.83 | 71.56 | 73.23 | 81.38 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 292 | 230 | 423 | 305 | 303 | 302 | 301 | 304 | 299 | 294 | 274 | 436 | 424 | 300 | 447 | 166 |
| **Route 7** | Arrival time | 27.12 | 28.35 | 31.68 | 36.13 | 38.95 | 42.5 | 45.42 | 49.45 | 54.03 | 55.76 | 59.48 | 59.48 | 62.36 | 63.78 | 72.31 | 73.21 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 329 | 325 | 326 | 330 | 323 | 327 | 322 | 321 | 332 | 324 | 328 | 180 | 181 | 182 | 183 | 175 |
| **Route 8** | Arrival time | 15.85 | 18.2 | 18.2 | 20.73 | 23.56 | 26.31 | 27.74 | 30.66 | 34.16 | 39.38 | 40.76 | 63.16 | 65.26 | 69.73 | 75.4 | 90.98 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 370 | 375 | 374 | 373 | 372 | 371 | 90 | 377 | 378 | 28 | 24 | 23 | 22 | 21 | 25 | 20 |
| **Route 9** | Arrival time | 12.7 | 15.28 | 19.4 | 20.18 | 24.51 | 27.99 | 34.12 | 34.89 | 40.32 | 50.24 | 65.77 | 68 | 71.52 | 75.6 | 77.23 | 78.81 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 264 | 260 | 445 | 444 | 250 | 251 | 257 | 128 | 158 | 159 | 165 | 288 | 194 | 169 | 143 | 135 |
| **Route 10** | Arrival time | 10.9 | 12.57 | 15.85 | 18.27 | 20.19 | 21.47 | 22.59 | 45.74 | 45.74 | 46.87 | 49.27 | 53.99 | 57.01 | 60.46 | 63.64 | 71.32 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 117 | 163 | 397 | 104 | 171 | 137 | 138 | 282 | 284 | 285 | 160 | 161 | 440 | 364 | 185 | 187 |
| **Route 11** | Arrival time | 29.43 | 34.93 | 43.76 | 53.79 | 64.02 | 64.65 | 67.78 | 73.03 | 75.93 | 75.93 | 78.98 | 81.33 | 83.93 | 87 | 89.7 | 93.1 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 46 | 89 | 214 | 243 | 247 | 367 | 249 | 248 | 245 | 246 | 213 | 360 | 244 | 242 | 239 | 219 |
| **Route 12** | Arrival time | 27.27 | 44.25 | 62.92 | 68.29 | 73.01 | 75.36 | 75.66 | 77.26 | 80.28 | 81.21 | 83.29 | 84.54 | 85.77 | 87.24 | 93.46 | 96.33 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 420 | 353 | 58 | 59 | 139 | 60 | 354 | 36 | 31 | 32 | 62 | 61 | 71 | 72 | 65 | 67 |
| **Route 13** | Arrival time | 12.88 | 15.28 | 18.98 | 18.98 | 18.98 | 19.51 | 20.98 | 23.06 | 26.61 | 26.94 | 28.87 | 32.49 | 36.12 | 36.12 | 44.57 | 46.45 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 313 | 315 | 317 | 311 | 316 | 91 | 92 | 14 | 16 | 26 | 17 | 15 | 19 | 18 | 27 | 96 |
| **Route 14** | Arrival time | 9.03 | 13.5 | 17.22 | 20.39 | 23.09 | 26.92 | 34.05 | 42.97 | 49.22 | 55.3 | 61.92 | 70.5 | 76.88 | 84.06 | 96.98 | 117.28 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 100 | 112 | 392 | 110 | 130 | 446 | 120 | 121 | 122 | 124 | 149 | 148 | 146 | 147 | 125 | 296 |
| **Route 15** | Arrival time | 23.77 | 32.65 | 36.33 | 45.6 | 50.63 | 54.25 | 55.23 | 57.01 | 57.71 | 60.31 | 66.58 | 70.16 | 71.58 | 74.68 | 79.63 | 94.88 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 224 | 229 | 63 | 429 | 234 | 428 | 425 | 427 | 68 | 439 | 430 | 421 | 412 | 422 | 295 | 293 |
| **Route 16** | Arrival time | 19.28 | 20.21 | 25.48 | 26.78 | 28.26 | 31.31 | 33.31 | 34.96 | 36.73 | 39.28 | 40.25 | 46.87 | 50.32 | 53.29 | 56.14 | 61.11 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 341 | 340 | 339 | 233 | 195 | 54 | 49 | 344 | 343 | 47 | 365 | | | | | |
| **Route 17** | Arrival time | 32.27 | 37.09 | 47.44 | 59.74 | 65.56 | 70.48 | 78.18 | 88.01 | 90.31 | 102.61 | 117.73 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 42 | 43 | 37 | 38 | 41 | 39 | 415 | 417 | 416 | 414 | 413 | 12 | 48 | 45 | 44 | 410 |
| **Route 18** | Arrival time | 19 | 22.18 | 23.06 | 23.68 | 29.78 | 32.01 | 36.86 | 40.84 | 42.92 | 46.27 | 52.32 | 62.35 | 68.88 | 72.31 | 76.58 | 83.1 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 73 | 79 | 277 | 81 | 276 | 297 | 275 | 298 | 426 | 162 | 177 | 188 | 289 | 186 | 240 | 237 |
| **Route 19** | Arrival time | 18.53 | 18.88 | 22.26 | 24.41 | 29.34 | 32.27 | 34.19 | 40.72 | 51.12 | 61.55 | 67.03 | 75 | 81.32 | 83.1 | 89.35 | 97.77 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 178 | 176 | 174 | 173 | 399 | 400 | 398 | 401 | 402 | 404 | 179 | | | | | |
| **Route 20** | Arrival time | 33.22 | 38.9 | 54.92 | 62.85 | 85.2 | 85.2 | 86.63 | 86.63 | 86.63 | 86.63 | 99.08 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 82 | 448 | 66 | 69 | 83 | 84 | 291 | 74 | 75 | 76 | 77 | 78 | 30 | 29 | 409 | 281 |
| **Route 21** | Arrival time | 18.53 | 22.9 | 23.4 | 23.5 | 25.8 | 26.77 | 29.47 | 34.4 | 35.23 | 37.01 | 39.06 | 42.48 | 48.48 | 51.96 | 57.61 | 67.29 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 207 | 206 | 204 | 202 | 199 | 205 | 203 | 198 | 197 | 209 | 210 | 211 | 8 | 9 | 7 | 10 |
| **Route 22** | Arrival time | 26.88 | 28.68 | 31.76 | 32.18 | 33.7 | 37.3 | 44.4 | 48.9 | 51.38 | 61.5 | 66.77 | 72.07 | 82.7 | 84.38 | 85.95 | 85.95 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 225 | 346 | 55 | 53 | 52 | 238 | 191 | 164 | 369 | 368 | 441 | 366 | 442 | 215 | 216 | 217 |
| **Route 23** | Arrival time | 18.4 | 21.3 | 29.05 | 32.88 | 37.88 | 49.81 | 61.08 | 64.73 | 68.28 | 71.15 | 74.22 | 76.59 | 81.51 | 83.09 | 86.89 | 86.89 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 433 | 80 | 431 | 278 | 434 | 435 | 270 | 269 | 268 | 432 | 272 | 273 | 235 | 232 | 227 | 228 |
| **Route 24** | Arrival time | 19.2 | 19.42 | 23.44 | 27.47 | 33.94 | 37.32 | 42.62 | 45.34 | 50.67 | 59.69 | 62.49 | 63.67 | 69.25 | 71.93 | 74.25 | 76.88 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 236 | 443 | 357 | 223 | 359 | 212 | 358 | 226 | 50 | 411 | 51 | 57 | 56 | 345 | 196 | 231 |
| **Route 25** | Arrival time | 22.2 | 27.32 | 29.14 | 33.19 | 36.09 | 40.52 | 42.05 | 51.28 | 59.56 | 62.68 | 67.65 | 70.83 | 72.6 | 80.23 | 93.11 | 101.18 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |

Table 20. Routing detail of Instance 3. Part 1.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 403 | 405 | 184 | 172 | 266 | 271 | 393 | 394 | 116 | 115 | 118 | | | | | |
| **Route 26** | Arrival time | 21.68 | 21.68 | 34.68 | 47.95 | 65.1 | 71.18 | 87.88 | 91.06 | 95.21 | 97.26 | 98.56 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 312 | 314 | 449 | 64 | 395 | 114 | 267 | | | | | | | | | |
| **Route 27** | Arrival time | 7.23 | 10.43 | 16.58 | 48.43 | 77.05 | 91.13 | 110.61 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 11 | 13 | 5 | 2 | 3 | 4 | 263 | 262 | 261 | 356 | 259 | 252 | 255 | 254 | 256 | 6 |
| **Route 28** | Arrival time | 7.33 | 9.21 | 15.93 | 17.9 | 18.55 | 21.42 | 25.49 | 29.24 | 30.22 | 33.95 | 37.02 | 39.82 | 45.09 | 47.01 | 49.69 | 55.11 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 320 | 319 | 318 | 280 | 279 | 306 | 333 | 347 | 40 | 35 | 438 | 437 | | | | |
| **Route 29** | Arrival time | 9.65 | 19.68 | 27.6 | 28.95 | 32.85 | 35.83 | 47.76 | 64.81 | 71.36 | 83.64 | 93.24 | 103.27 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 355 | 418 | 351 | 352 | 419 | 258 | 253 | 349 | 350 | 408 | 406 | 407 | 348 | 376 | 95 | 265 |
| **Route 30** | Arrival time | 18.03 | 21.31 | 24.33 | 26.96 | 30.84 | 40.79 | 47.66 | 57.79 | 57.79 | 62.66 | 67.13 | 69.68 | 74.11 | 86.96 | 89.06 | 92.78 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 94 | 99 | 97 | 98 | 1 | | | | | | | | | | | |
| **Route 31** | Arrival time | 9.33 | 16.08 | 20 | 20 | 30.77 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |

Table 21. Routing detail of Instance 3. Part 2.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 33 | 190 | 189 | 131 | 143 | 169 | 144 | 168 | 192 | 167 | 288 | 132 | 285 | 188 | 365 |
| **Route 1** | Arrival time | 19.53 | 33.2 | 35.77 | 37.55 | 40.03 | 41.63 | 44.15 | 46.62 | 48.64 | 49.12 | 52.35 | 60 | 63.15 | 68.08 | 73.88 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 |
| | Nodes | 193 | 151 | 150 | 157 | 152 | 389 | 154 | 387 | 153 | 388 | 386 | 391 | 107 | 108 | |
| **Route 2** | Arrival time | 32.37 | 36.64 | 38.37 | 41.2 | 45.22 | 49.84 | 51.54 | 52.51 | 52.84 | 52.84 | 53.29 | 59.01 | 60.66 | 63.74 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | |
| | Nodes | 86 | 156 | 105 | 155 | 163 | 221 | | | | | | | | | |
| **Route 3** | Arrival time | 17.43 | 40.65 | 48.43 | 52.56 | 58.09 | 69.32 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | |
| | Nodes | 201 | 200 | 334 | 336 | 337 | 208 | | | | | | | | | |
| **Route 4** | Arrival time | 27.33 | 29.41 | 37.11 | 43.26 | 54.28 | 74.9 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | |
| | Nodes | 362 | 363 | 289 | 187 | 185 | 186 | 136 | 134 | 135 | 282 | 283 | 331 | | | |
| **Route 5** | Arrival time | 28.83 | 29.63 | 33.45 | 37.2 | 39.32 | 41.47 | 48.97 | 51.09 | 51.09 | 54.17 | 58.07 | 64.29 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | |
| | Nodes | 380 | 85 | 308 | 385 | 384 | 307 | 93 | 377 | 90 | 378 | 379 | 87 | 267 | 96 | |
| **Route 6** | Arrival time | 12.75 | 22.28 | 26.48 | 29.66 | 32.64 | 36.32 | 42.17 | 47.92 | 48.24 | 53.37 | 57.25 | 60.98 | 69.68 | 79.9 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | |
| | Nodes | 111 | 109 | 390 | 119 | 127 | 126 | 123 | 122 | 121 | 446 | 110 | | | | |
| **Route 7** | Arrival time | 27.78 | 30.73 | 38.81 | 42.23 | 46.95 | 48.77 | 48.97 | 49.9 | 50.6 | 53.35 | 60.43 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | |
| | Nodes | 292 | 230 | 423 | 305 | 303 | 302 | 301 | 304 | 299 | 293 | 159 | | | | |
| **Route 8** | Arrival time | 27.12 | 28.35 | 31.68 | 36.13 | 38.95 | 42.5 | 45.42 | 49.45 | 54.03 | 58.08 | 69.96 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | |
| | Nodes | 447 | 166 | 145 | 70 | 138 | 140 | 141 | 133 | 286 | 287 | 170 | 290 | | | |
| **Route 9** | Arrival time | 29.22 | 30.12 | 37.59 | 37.76 | 39.74 | 40.71 | 41.94 | 47.17 | 52.25 | 53.58 | 57.68 | 67.96 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | |
| | Nodes | 329 | 172 | 182 | 180 | 181 | 183 | 176 | | | | | | | | |
| **Route 10** | Arrival time | 15.85 | 25.35 | 38.65 | 42.42 | 44.52 | 49.97 | 65.55 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | |
| | Nodes | 370 | 371 | 375 | 374 | 372 | 373 | 97 | 98 | 99 | 81 | 426 | 448 | | | |
| **Route 11** | Arrival time | 12.7 | 17.68 | 22.55 | 26.67 | 30.79 | 34.31 | 40.29 | 40.29 | 42.14 | 55.21 | 62.79 | 68.26 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | |
| | Nodes | 264 | 254 | 256 | 6 | 255 | 444 | 250 | 251 | 257 | 31 | 32 | 62 | 61 | 72 | |
| **Route 12** | Arrival time | 10.9 | 18.53 | 21.21 | 26.63 | 30.18 | 38.18 | 40.1 | 41.38 | 42.5 | 53.37 | 53.7 | 55.63 | 59.25 | 62.88 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | |
| | Nodes | 117 | 397 | 104 | 393 | 26 | | | | | | | | | | |
| **Route 13** | Arrival time | 29.43 | 38.4 | 48.43 | 56.1 | 79.88 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | |
| | Nodes | 46 | 89 | 247 | | | | | | | | | | | | |
| **Route 14** | Arrival time | 27.27 | 44.25 | 64.2 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | | | | |
| | Nodes | 300 | 274 | 436 | 424 | 294 | 296 | 297 | 275 | 276 | 439 | 430 | 428 | 421 | 438 | |
| **Route 15** | Arrival time | 26.2 | 28.48 | 28.48 | 31.36 | 33.69 | 36.89 | 40.92 | 42.84 | 48.12 | 51.82 | 52.79 | 56.02 | 59.67 | 67.24 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | |
| | Nodes | 420 | 355 | 58 | 139 | 354 | 60 | 36 | 35 | 59 | 351 | 352 | 353 | 437 | 419 | 369 |
| **Route 16** | Arrival time | 12.88 | 18.03 | 24.36 | 24.36 | 25.31 | 26.79 | 28.87 | 31.62 | 35.75 | 39.38 | 42.01 | 43.21 | 46.64 | 50.36 | 64.36 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 |
| | Nodes | 313 | 312 | 311 | 317 | 316 | 315 | 91 | 92 | 14 | 17 | | | | | |
| **Route 17** | Arrival time | 9.42 | 12.75 | 21.07 | 23.55 | 26.57 | 29.77 | 34.95 | 42.08 | 51 | 62.1 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | |
| | Nodes | 142 | 137 | 34 | 171 | 284 | 161 | 162 | | | | | | | | |
| **Route 18** | Arrival time | 32.28 | 35.75 | 42.6 | 45.38 | 53.15 | 56.88 | 61.91 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | |
| | Nodes | 100 | 106 | 103 | 101 | 102 | 113 | 392 | 395 | 40 | | | | | | |
| **Route 19** | Arrival time | 23.77 | 33.64 | 39.24 | 42.67 | 42.67 | 45.05 | 51.62 | 57.37 | 82.37 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | |
| | Nodes | 224 | 409 | 422 | 295 | 149 | 148 | 146 | 128 | 158 | 177 | 366 | | | | |
| **Route 20** | Arrival time | 19.28 | 24.1 | 27.07 | 29.92 | 37.9 | 41.48 | 42.9 | 49.97 | 49.97 | 56.87 | 67.14 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | |
| | Nodes | 341 | 340 | 342 | 195 | 52 | 57 | | | | | | | | | |
| **Route 21** | Arrival time | 32.27 | 37.09 | 44.22 | 51.24 | 61.76 | 66.08 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | |
| | Nodes | 42 | 43 | 416 | 414 | 415 | 41 | 417 | 196 | 37 | 38 | | | | | |
| **Route 22** | Arrival time | 19 | 22.18 | 30.65 | 34 | 37.93 | 44.33 | 54.25 | 59.9 | 65.18 | 65.8 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | |
| | Nodes | 165 | 194 | 160 | 440 | 364 | 222 | 218 | | | | | | | | |
| **Route 23** | Arrival time | 31.1 | 34.08 | 42.38 | 45.38 | 48.45 | 58.17 | 61.94 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | |
| | Nodes | 73 | 79 | 277 | 68 | 425 | 427 | 412 | 63 | 429 | 65 | 69 | 66 | 234 | 431 | 278 |
| **Route 24** | Arrival time | 18.53 | 18.88 | 22.26 | 31.13 | 34.85 | 36.5 | 41.05 | 45.88 | 47.18 | 49.68 | 51.06 | 51.16 | 55.21 | 61.01 | 65.04 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 |
| | Nodes | 178 | 175 | 174 | | | | | | | | | | | | |
| **Route 25** | Arrival time | 33.22 | 38.9 | 54.92 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | | | | | | | | | | | | |

Table 22. Routing detail of Instance 4. Part 1.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 82 | 67 | 147 | 120 | 129 | 125 | 1 | | | | | |
| **Route 26** | Arrival time | 18.53 | 23.33 | 32.45 | 41.13 | 43.95 | 49.05 | 75.28 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 207 | 206 | 204 | 202 | 199 | 205 | 203 | 198 | 209 | | | |
| **Route 27** | Arrival time | 26.88 | 28.68 | 31.76 | 32.18 | 33.7 | 37.3 | 44.4 | 48.9 | 58.6 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | |
| | Nodes | 225 | 413 | 12 | 48 | 45 | 47 | 367 | 217 | | | | |
| **Route 28** | Arrival time | 18.4 | 24.48 | 34.51 | 41.04 | 44.47 | 46.24 | 59.71 | 62.81 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | |
| | Nodes | 433 | 298 | 281 | 191 | 84 | 235 | | | | | | |
| **Route 29** | Arrival time | 19.2 | 28.87 | 42.35 | 49.45 | 59.58 | 62.6 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | |
| | Nodes | 236 | 237 | 248 | 249 | 239 | 220 | 219 | 240 | | | | |
| **Route 30** | Arrival time | 22.2 | 25.75 | 29.23 | 30.83 | 35.8 | 39.98 | 46.96 | 57.04 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | |
| | Nodes | 403 | 179 | 399 | 400 | 398 | 401 | 402 | 404 | 405 | | | |
| **Route 31** | Arrival time | 21.68 | 35.96 | 43.63 | 43.63 | 45.06 | 45.06 | 45.06 | 45.06 | 50.99 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | |
| | Nodes | 335 | 338 | | | | | | | | | | |
| **Route 32** | Arrival time | 37.32 | 52.7 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | | | | | | | | | | |
| | Nodes | 449 | 450 | 396 | 112 | | | | | | | | |
| **Route 33** | Arrival time | 12.26 | 37.83 | 39.5 | 46.58 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | |
| | Nodes | 11 | 325 | 323 | 326 | 330 | 327 | 322 | 321 | 332 | 324 | 328 | |
| **Route 34** | Arrival time | 12.42 | 24.42 | 28.6 | 32.5 | 35.03 | 37.98 | 39.41 | 42.33 | 45.83 | 51.05 | 52.43 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | |
| | Nodes | 262 | 356 | 260 | 258 | 445 | 418 | 75 | 76 | 77 | 78 | 83 | 227 |
| **Route 35** | Arrival time | 12.45 | 15.77 | 19.49 | 25.21 | 28.93 | 36.88 | 42.53 | 44.31 | 46.36 | 49.78 | 55.11 | 61.76 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 |
| | Nodes | 24 | 23 | 22 | 21 | 25 | 20 | 15 | 16 | 27 | 309 | | |
| **Route 36** | Arrival time | 20.92 | 23.15 | 26.67 | 30.75 | 32.38 | 33.96 | 40.39 | 43.31 | 51.38 | 59.9 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | |
| | Nodes | 71 | 291 | 30 | 29 | 229 | 231 | 228 | 232 | 74 | | | |
| **Route 37** | Arrival time | 20.35 | 25.12 | 31.57 | 35.05 | 37.63 | 41.26 | 46.89 | 52.21 | 60.88 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | |
| | Nodes | 271 | 434 | 272 | 164 | 441 | 216 | 245 | 360 | | | | |
| **Route 38** | Arrival time | 12.88 | 20.26 | 24.86 | 40.68 | 46.58 | 52.21 | 57.18 | 59.93 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | |
| | Nodes | 39 | 344 | 343 | 49 | 233 | | | | | | | |
| **Route 39** | Arrival time | 17.53 | 33.31 | 35.61 | 42.69 | 49.24 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | |
| | Nodes | 238 | 214 | 243 | 242 | 212 | 213 | 359 | | | | | |
| **Route 40** | Arrival time | 30.83 | 40.26 | 45.63 | 50.08 | 53.58 | 56.75 | 61.18 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 124 | 130 | 115 | 118 | 116 | 357 | 358 | | | | | |
| **Route 41** | Arrival time | 26.78 | 33.08 | 46.25 | 47.55 | 50.1 | 53.12 | 54.8 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 320 | 319 | 184 | 7 | | | | | | | | |
| **Route 42** | Arrival time | 14.66 | 24.69 | 41.24 | 62.36 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | |
| | Nodes | 318 | 314 | 18 | 19 | 349 | 350 | | | | | | |
| **Route 43** | Arrival time | 15.17 | 25.64 | 38.69 | 45.69 | 64.84 | 64.84 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | |
| | Nodes | 244 | 361 | 241 | 215 | 442 | 223 | 246 | | | | | |
| **Route 44** | Arrival time | 25 | 28.6 | 30.13 | 36.5 | 38.93 | 44.3 | 49.13 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 310 | 28 | 382 | 383 | 381 | 88 | 269 | 435 | 432 | | | |
| **Route 45** | Arrival time | 17.17 | 25.59 | 36.59 | 39.54 | 41.46 | 43.93 | 53.86 | 57.79 | 61.12 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | |
| | Nodes | 64 | | | | | | | | | | | |
| **Route 46** | Arrival time | 33.07 | | | | | | | | | | | |
| | Vehicle load | 12 | | | | | | | | | | | |
| | Nodes | 4 | 261 | 263 | 2 | 5 | 3 | 253 | 9 | 8 | 13 | | |
| **Route 47** | Arrival time | 17.62 | 26.15 | 30.87 | 36.25 | 38.22 | 40.55 | 48.63 | 55.31 | 56.99 | 64.06 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | |
| | Nodes | 55 | 51 | 50 | 411 | 410 | 44 | 53 | | | | | |
| **Route 48** | Arrival time | 20.68 | 25.73 | 30.33 | 33.45 | 34.57 | 43.35 | 54.68 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | |
| | Nodes | 394 | 114 | 268 | 376 | | | | | | | | |
| **Route 49** | Arrival time | 20.27 | 36.77 | 52.5 | 60.08 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | |
| | Nodes | 339 | 54 | 56 | 345 | | | | | | | | |
| **Route 50** | Arrival time | 29.07 | 43.85 | 50.75 | 58.38 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | |

Table 23. Routing detail of Instance 4. Part 2.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Nodes | 10 | 210 | 211 | 347 | | |
| **Route 51** | Arrival time | 19.63 | 32.35 | 37.65 | 51.63 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | |
| | Nodes | 226 | 443 | 368 | 80 | 273 | |
| **Route 52** | Arrival time | 20.27 | 30.79 | 35.69 | 52.24 | 55.66 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | |
| | Nodes | 197 | 346 | 266 | | | |
| **Route 53** | Arrival time | 20.72 | 33.79 | 50.94 | | | |
| | Vehicle load | 12 | 24 | 36 | | | |
| | Nodes | 280 | 333 | 406 | 407 | 259 | 252 |
| **Route 54** | Arrival time | 20.49 | 34.27 | 44.79 | 47.34 | 56.36 | 59.16 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 |
| | Nodes | 94 | 270 | 265 | 95 | 408 | |
| **Route 55** | Arrival time | 21.01 | 31.23 | 44.26 | 46.06 | 54.98 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | |
| | Nodes | 348 | 306 | 279 | | | |
| **Route 56** | Arrival time | 27.27 | 39.64 | 42.59 | | | |
| | Vehicle load | 12 | 24 | 36 | | | |
| | Nodes | 173 | | | | | |
| **Route 57** | Arrival time | 29.18 | | | | | |
| | Vehicle load | 12 | | | | | |

Table 24. Routing detail of Instance 4. Part 3.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 33 | 190 | 189 | 131 | 143 | 169 | 144 | 168 | 192 | 167 | 151 | 157 | 152 | 154 | 387 | 159 |
| **Route 1** | Arrival time | 19.53 | 33.2 | 35.77 | 37.55 | 40.03 | 41.63 | 44.15 | 46.62 | 48.64 | 49.12 | 54.49 | 58.17 | 62.19 | 66.44 | 67.41 | 73.78 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 193 | 150 | 153 | 388 | 390 | 389 | 391 | 107 | 155 | 108 | 106 | 132 | | | | |
| **Route 2** | Arrival time | 32.37 | 36.3 | 39.73 | 39.73 | 43.08 | 43.45 | 46.07 | 47.72 | 51.1 | 56.67 | 59.3 | 75.13 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 86 | 85 | 308 | 156 | 105 | 119 | 386 | 162 | | | | | | | | |
| **Route 3** | Arrival time | 17.43 | 18.41 | 22.61 | 43.71 | 51.49 | 57.62 | 60.77 | 71 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |
| | Nodes | 201 | 200 | 334 | 336 | 337 | 208 | | | | | | | | | | |
| **Route 4** | Arrival time | 27.33 | 29.41 | 37.11 | 43.26 | 54.28 | 74.9 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 362 | 363 | 289 | 185 | 187 | 188 | 160 | 161 | 440 | 364 | 284 | 285 | 282 | 283 | 331 | 221 |
| **Route 5** | Arrival time | 28.83 | 29.63 | 33.45 | 36.53 | 39.93 | 42.85 | 44.42 | 46.77 | 49.37 | 52.44 | 57.92 | 57.92 | 59.04 | 62.94 | 69.16 | 75.88 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 380 | 383 | 88 | 382 | 385 | 384 | 307 | 93 | 310 | 309 | 20 | 21 | 25 | 17 | 26 | |
| **Route 6** | Arrival time | 12.75 | 17.27 | 20.67 | 23.3 | 30.97 | 33.95 | 37.63 | 43.48 | 49.01 | 50.78 | 59.86 | 61.53 | 63.16 | 67.61 | 77.96 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | |
| | Nodes | 111 | 109 | 127 | 126 | 129 | 123 | 122 | 121 | 120 | 446 | 130 | 110 | 392 | 102 | 103 | 393 |
| **Route 7** | Arrival time | 27.78 | 30.73 | 35.58 | 37.4 | 37.4 | 37.6 | 38.53 | 39.23 | 41.01 | 41.99 | 44.99 | 50.49 | 56.62 | 61.8 | 64.65 | 72.28 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 292 | 230 | 423 | 305 | 303 | 302 | 301 | 304 | 299 | 294 | 295 | 421 | 426 | 448 | | |
| **Route 8** | Arrival time | 27.12 | 28.35 | 31.68 | 36.13 | 38.95 | 42.5 | 45.42 | 49.45 | 54.03 | 55.76 | 59.26 | 65.28 | 71.7 | 77.17 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | | |
| | Nodes | 447 | 166 | 288 | 194 | 70 | 145 | 136 | 133 | 134 | 135 | 286 | 287 | 170 | 290 | 365 | |
| **Route 9** | Arrival time | 29.22 | 30.12 | 33.17 | 36.19 | 43.54 | 45.62 | 49.72 | 51.84 | 51.84 | 51.84 | 56.92 | 58.25 | 62.35 | 72.63 | 77.46 | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | |
| | Nodes | 329 | 325 | 323 | 326 | 330 | 327 | 322 | 321 | 332 | 324 | 328 | 401 | 404 | 405 | | |
| **Route 10** | Arrival time | 15.85 | 18.2 | 22.38 | 26.28 | 28.81 | 31.76 | 33.19 | 36.11 | 39.61 | 44.83 | 46.21 | 64.63 | 64.63 | 70.56 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | | |
| | Nodes | 370 | 375 | 372 | 371 | 90 | 377 | 378 | 379 | 87 | 28 | 14 | | | | | |
| **Route 11** | Arrival time | 12.7 | 15.28 | 20.88 | 24.36 | 30.49 | 31.26 | 36.69 | 40.57 | 44.3 | 53.5 | 70.48 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 264 | 254 | 256 | 6 | 255 | 444 | 250 | 251 | 257 | 31 | 32 | 62 | 61 | 72 | 74 | 40 |
| **Route 12** | Arrival time | 10.9 | 18.53 | 21.21 | 26.63 | 30.18 | 38.18 | 40.1 | 41.38 | 42.5 | 53.37 | 53.7 | 55.63 | 59.25 | 62.88 | 68.6 | 84.42 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 117 | 163 | 34 | 171 | 137 | 140 | 141 | 138 | 191 | | | | | | | |
| **Route 13** | Arrival time | 29.43 | 34.93 | 42.38 | 45.16 | 45.79 | 49.47 | 50.7 | 55.93 | 62.45 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | | |
| | Nodes | 46 | 89 | 243 | 247 | 186 | | | | | | | | | | | |
| **Route 14** | Arrival time | 27.27 | 44.25 | 59.73 | 64.45 | 70.28 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 300 | 274 | 436 | 424 | 293 | 296 | 297 | 275 | 276 | 439 | 430 | 428 | 427 | 65 | 66 | 96 |
| **Route 15** | Arrival time | 26.2 | 28.48 | 28.48 | 31.36 | 33.08 | 38.06 | 42.09 | 44.01 | 49.29 | 52.99 | 53.96 | 57.19 | 60.84 | 66.07 | 67.45 | 86.97 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 420 | 355 | 60 | 58 | 139 | 354 | 59 | 36 | 35 | 232 | 29 | 63 | 429 | 234 | 425 | 412 |
| **Route 16** | Arrival time | 12.88 | 18.03 | 23.83 | 24.36 | 24.36 | 25.31 | 26.26 | 27.81 | 30.56 | 36.94 | 38.96 | 44.38 | 45.68 | 47.16 | 51.96 | 55.36 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 313 | 315 | 311 | 317 | 316 | 91 | 92 | 450 | | | | | | | | |
| **Route 17** | Arrival time | 9.03 | 13.5 | 20.58 | 23.06 | 26.08 | 29.91 | 37.04 | 60.41 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |
| | Nodes | 142 | 165 | 128 | 158 | 148 | 125 | | | | | | | | | | |
| **Route 18** | Arrival time | 32.28 | 38.48 | 45.56 | 45.56 | 52.34 | 58.12 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 100 | 101 | 113 | 112 | 395 | 115 | 118 | 116 | 357 | 216 | 217 | 366 | 369 | | | |
| **Route 19** | Arrival time | 23.77 | 30.3 | 32.68 | 35.55 | 42.03 | 50.58 | 51.88 | 54.43 | 57.45 | 61.37 | 61.37 | 64.19 | 69.56 | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | | | |
| | Nodes | 224 | 229 | 409 | 422 | 149 | 146 | 147 | 298 | 431 | 278 | | | | | | |
| **Route 20** | Arrival time | 19.28 | 20.21 | 24.59 | 27.56 | 38.23 | 41 | 44.1 | 55.88 | 64.96 | 68.99 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | | |
| | Nodes | 341 | 340 | 342 | 339 | 195 | 57 | | | | | | | | | | |
| **Route 21** | Arrival time | 32.27 | 37.09 | 44.22 | 52.7 | 62.67 | 72.54 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 42 | 43 | 416 | 414 | 417 | 415 | 41 | 37 | 38 | 196 | 438 | | | | | |
| **Route 22** | Arrival time | 19 | 22.18 | 30.65 | 34 | 37.57 | 43.55 | 49.95 | 56.05 | 56.67 | 64.22 | 72.64 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 73 | 79 | 277 | 68 | 67 | 69 | 83 | 84 | 291 | 71 | 235 | 227 | 231 | 353 | | |
| **Route 23** | Arrival time | 18.53 | 18.88 | 22.26 | 31.13 | 35.43 | 36.03 | 38.33 | 39.3 | 42 | 44.22 | 49.3 | 52.25 | 58.73 | 71.15 | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | | |
| | Nodes | 178 | 175 | 176 | 182 | 180 | 181 | | | | | | | | | | |
| **Route 24** | Arrival time | 33.22 | 38.9 | 38.9 | 54.65 | 58.42 | 60.52 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 82 | 433 | 434 | 80 | 81 | 164 | 281 | 177 | | | | | | | | |
| **Route 25** | Arrival time | 18.53 | 24.28 | 28.26 | 32.31 | 34.11 | 45.66 | 51.53 | 57.35 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |

Table 25. Routing detail of Instance 4’. Part 1.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 207 | 206 | 204 | 202 | 199 | 205 | 203 | 198 | 197 | 209 | 1 | | | | | |
| **Route 26** | Arrival time | 26.88 | 28.68 | 31.76 | 32.18 | 33.7 | 37.3 | 44.4 | 48.9 | 51.38 | 61.5 | 78.22 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 225 | 344 | 343 | 49 | 233 | 54 | 53 | 52 | | | | | | | | |
| **Route 27** | Arrival time | 18.4 | 27.2 | 29.5 | 36.58 | 43.13 | 53.93 | 61.91 | 66.91 | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | | | | | | | | |
| | Nodes | 236 | 248 | 367 | 249 | 222 | 218 | 220 | 219 | 240 | | | | | | | |
| **Route 28** | Arrival time | 22.2 | 26.18 | 28.9 | 29.2 | 38.7 | 42.47 | 42.47 | 49.45 | 59.53 | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | | | | | | | |
| | Nodes | 403 | 179 | 399 | 400 | 398 | 402 | 184 | | | | | | | | | |
| **Route 29** | Arrival time | 21.68 | 35.96 | 43.63 | 43.63 | 45.06 | 45.06 | 58.33 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 335 | 338 | | | | | | | | | | | | | | |
| **Route 30** | Arrival time | 37.32 | 52.7 | | | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | | | | | | | | | | | | | | |
| | Nodes | 312 | 319 | 183 | 172 | | | | | | | | | | | | |
| **Route 31** | Arrival time | 7.23 | 19.58 | 41.21 | 55.91 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | | | |
| | Nodes | 449 | 24 | 23 | 22 | 27 | 19 | 18 | | | | | | | | | |
| **Route 32** | Arrival time | 8.92 | 28.32 | 30.55 | 34.07 | 45.87 | 56.05 | 63.23 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 11 | 262 | 356 | 260 | 445 | 418 | 75 | 76 | 77 | 78 | 273 | 272 | 435 | 432 | 269 | 267 |
| **Route 33** | Arrival time | 7.42 | 13.7 | 17.02 | 20.74 | 24.02 | 31.97 | 37.62 | 39.4 | 41.45 | 44.87 | 47.45 | 48.63 | 54.11 | 57.44 | 64.37 | 72.12 |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| | Nodes | 271 | 270 | 268 | 104 | 242 | 359 | | | | | | | | | | |
| **Route 34** | Arrival time | 12.43 | 19.01 | 24.39 | 47.36 | 60.88 | 66.21 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 39 | 413 | 12 | 48 | 45 | 47 | 411 | | | | | | | | | |
| **Route 35** | Arrival time | 17.53 | 29.68 | 39.71 | 46.24 | 49.67 | 51.44 | 61.52 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 396 | 397 | 241 | 245 | 360 | | | | | | | | | | | |
| **Route 36** | Arrival time | 26.28 | 39.56 | 54.88 | 60.38 | 63.13 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 238 | 214 | 361 | 239 | 212 | 213 | | | | | | | | | | |
| **Route 37** | Arrival time | 30.83 | 40.26 | 48.84 | 50.86 | 58.36 | 61.53 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 2 | 5 | 3 | 4 | 263 | 261 | 253 | 9 | 8 | 7 | 211 | | | | | |
| **Route 38** | Arrival time | 24.87 | 26.84 | 29.17 | 32.04 | 36.11 | 40.91 | 46.14 | 52.82 | 54.5 | 56.57 | 67.37 | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | | | | | |
| | Nodes | 10 | 210 | 347 | 345 | 346 | 56 | | | | | | | | | | |
| **Route 39** | Arrival time | 14.63 | 27.35 | 40.87 | 50.9 | 55.1 | 61.63 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 13 | 55 | 51 | 50 | | | | | | | | | | | | |
| **Route 40** | Arrival time | 29.67 | 48.2 | 53.25 | 57.85 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | | | | | | | | | | | | |
| | Nodes | 15 | 16 | 394 | 114 | 97 | | | | | | | | | | | |
| **Route 41** | Arrival time | 14.02 | 16.94 | 31.92 | 48.42 | 70.29 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 30 | 228 | 44 | 410 | 226 | 358 | 443 | | | | | | | | | |
| **Route 42** | Arrival time | 20.08 | 25.7 | 35.83 | 42.35 | 48.38 | 55.18 | 59.88 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | | | | | | | | | |
| | Nodes | 124 | 237 | 442 | 215 | 246 | 349 | | | | | | | | | | |
| **Route 43** | Arrival time | 26.78 | 44.88 | 46.76 | 48.34 | 53.61 | 71.73 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 320 | 318 | 280 | 306 | 279 | 314 | 374 | 373 | 98 | 99 | 381 | 376 | | | | |
| **Route 44** | Arrival time | 9.66 | 17.51 | 18.86 | 22.94 | 25.89 | 33.19 | 45.11 | 45.89 | 51.87 | 53.72 | 59.17 | 66.3 | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | | | | |
| | Nodes | 244 | 223 | 441 | 368 | 419 | 437 | | | | | | | | | | |
| **Route 45** | Arrival time | 25 | 32.68 | 41.11 | 44.13 | 57.96 | 62.03 | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | | | | | | | | | | |
| | Nodes | 64 | | | | | | | | | | | | | | | |
| **Route 46** | Arrival time | 33.07 | | | | | | | | | | | | | | | |
| | Vehicle load | 12 | | | | | | | | | | | | | | | |
| | Nodes | 94 | 95 | 265 | 351 | 352 | 252 | 259 | 258 | 350 | 406 | | | | | | |
| **Route 47** | Arrival time | 16.01 | 20.54 | 24.26 | 38.18 | 40.81 | 50.86 | 53.84 | 56.99 | 61.99 | 68.31 | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | | | | | | |
| | Nodes | 266 | 408 | 407 | 348 | 333 | | | | | | | | | | | |
| **Route 48** | Arrival time | 18.76 | 29.33 | 34.23 | 38.66 | 47.74 | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 48 | 60 | | | | | | | | | | | |
| | Nodes | 173 | | | | | | | | | | | | | | | |
| **Route 49** | Arrival time | 24.18 | | | | | | | | | | | | | | | |
| | Vehicle load | 12 | | | | | | | | | | | | | | | |
| | Nodes | 174 | | | | | | | | | | | | | | | |
| **Route 50** | Arrival time | 34.84 | | | | | | | | | | | | | | | |
| | Vehicle load | 12 | | | | | | | | | | | | | | | |

Table 26. Routing detail of Instance 4’. Part 2.

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 1 | 156 | 105 | 108 | 390 | 389 | 154 | 387 | 153 | 388 | 386 | 157 | 151 | 192 | 167 | 144 | 168 | 70 | 145 |
| **Route 1** | Arrival time | 2.4 | 17.5 | 25.28 | 26.5 | 34.5 | 34.87 | 36.57 | 37.54 | 37.87 | 37.87 | 38.32 | 40.45 | 45.43 | 47.51 | 47.99 | 50.86 | 53.33 | 57.13 | 59.21 |
| | Vehicle load | 9 | 20 | 34 | 43 | 53 | 62 | 73 | 85 | 93 | 103 | 116 | 127 | 139 | 148 | 157 | 165 | 174 | 185 | 197 |
| | Nodes | 306 | 280 | 318 | 4 | 180 | 181 | 182 | 183 | 175 | 176 | 178 | | | | | | | | |
| **Route 2** | Arrival time | 7.8 | 11.88 | 13.25 | 11.22 | 44.65 | 46.75 | 51.22 | 56.89 | 72.47 | 72.47 | 78.05 | | | | | | | | |
| | Vehicle load | 10 | 25 | 36 | 26 | 59 | 73 | 86 | 99 | 112 | 124 | 138 | | | | | | | | |
| | Nodes | 279 | 317 | 311 | 316 | 315 | 91 | 372 | 375 | 370 | 374 | 373 | 96 | 85 | 86 | 308 | 385 | 87 | | |
| **Route 3** | Arrival time | 9.08 | 15.31 | 18.48 | 21.18 | 24.38 | 29.56 | 37.09 | 39.57 | 43.44 | 46.69 | 47.47 | 51.32 | 64.39 | 65.41 | 68.59 | 71.77 | 77.52 | | |
| | Vehicle load | 15 | 29 | 42 | 54 | 67 | 79 | 91 | 102 | 110 | 120 | 132 | 146 | 157 | 166 | 178 | 189 | 200 | | |
| | Nodes | 320 | 325 | 326 | 329 | 330 | 323 | 327 | 322 | 321 | 332 | 324 | 328 | 399 | 400 | 398 | 402 | | | |
| **Route 4** | Arrival time | 9.65 | 22.45 | 22.45 | 25.03 | 28.6 | 31.43 | 34.18 | 35.61 | 38.53 | 42.03 | 47.25 | 48.63 | 71.05 | 71.05 | 72.48 | 72.48 | | | |
| | Vehicle load | 11 | 25 | 37 | 49 | 64 | 72 | 86 | 100 | 113 | 124 | 136 | 148 | 160 | 173 | 187 | 200 | | | |
| | Nodes | 348 | 406 | 263 | 262 | 261 | 356 | 445 | 444 | 190 | 189 | 131 | 132 | 283 | 142 | 140 | 141 | 169 | | |
| **Route 5** | Arrival time | 5.75 | 8.17 | 10.4 | 14.15 | 15.13 | 18.86 | 22.48 | 24.9 | 41.62 | 44.19 | 45.97 | 46.42 | 47.34 | 51.54 | 52.22 | 53.45 | 56.48 | | |
| | Vehicle load | 11 | 23 | 36 | 47 | 59 | 69 | 81 | 94 | 107 | 118 | 131 | 143 | 150 | 160 | 176 | 182 | 194 | | |
| | Nodes | 314 | 312 | 313 | 449 | 371 | 90 | 377 | 93 | 307 | 384 | 28 | 450 | 396 | | | | | | |
| **Route 6** | Arrival time | 6.43 | 9.15 | 12.5 | 22.3 | 29.82 | 35.95 | 36.72 | 42.52 | 45.74 | 46.76 | 54.53 | 76.75 | 78.42 | | | | | | |
| | Vehicle load | 12 | 26 | 40 | 52 | 62 | 77 | 89 | 101 | 113 | 125 | 137 | 151 | 167 | | | | | | |
| | Nodes | 407 | 4 | 2 | 5 | 3 | 253 | 6 | 255 | 254 | 256 | 251 | 250 | 257 | 128 | 158 | 159 | | | |
| **Route 7** | Arrival time | 6.52 | 11.22 | 15.09 | 17.06 | 19.39 | 27.47 | 33.25 | 36.8 | 38.72 | 41.4 | 47.82 | 49.12 | 50.57 | 73.72 | 73.72 | 74.85 | | | |
| | Vehicle load | 17 | 26 | 39 | 49 | 59 | 72 | 85 | 98 | 111 | 123 | 136 | 149 | 159 | 169 | 181 | 193 | | | |
| | Nodes | 408 | 259 | 252 | 260 | 264 | 9 | 8 | 7 | 10 | 210 | 207 | 206 | 204 | 202 | 200 | | | | |
| **Route 8** | Arrival time | 7.07 | 13.44 | 16.24 | 18.84 | 20.51 | 28.78 | 30.46 | 32.53 | 32.53 | 45.25 | 55.12 | 56.92 | 60 | 60.42 | 63.22 | | | | |
| | Vehicle load | 13 | 27 | 40 | 51 | 62 | 77 | 89 | 103 | 119 | 134 | 148 | 159 | 168 | 180 | 196 | | | | |
| | Nodes | 11 | 13 | 335 | 334 | 336 | 337 | | | | | | | | | | | | | |
| **Route 9** | Arrival time | 7.33 | 9.21 | 43.68 | 52.96 | 59.11 | 70.13 | | | | | | | | | | | | | |
| | Vehicle load | 9 | 21 | 31 | 41 | 52 | 63 | | | | | | | | | | | | | |
| | Nodes | 333 | 89 | 104 | 155 | 391 | 107 | 119 | 152 | | | | | | | | | | | |
| **Route 10** | Arrival time | 7.73 | 46.15 | 63.37 | 66.49 | 69.22 | 70.87 | 76.95 | 79.13 | | | | | | | | | | | |
| | Vehicle load | 15 | 27 | 37 | 47 | 59 | 70 | 84 | 92 | | | | | | | | | | | |
| | Nodes | 349 | 350 | 258 | 289 | 185 | 187 | 188 | 160 | 161 | 440 | 364 | 284 | 285 | 282 | 143 | 166 | | | |
| **Route 11** | Arrival time | 7.67 | 7.67 | 13.57 | 36.6 | 39.68 | 43.08 | 46 | 47.57 | 49.92 | 52.52 | 55.59 | 61.07 | 61.07 | 62.19 | 67.07 | 70.35 | | | |
| | Vehicle load | 13 | 25 | 39 | 51 | 65 | 75 | 88 | 100 | 112 | 124 | 135 | 145 | 161 | 176 | 185 | 196 | | | |
| | Nodes | 94 | 88 | 382 | 383 | 381 | 379 | 380 | 378 | 309 | 310 | 24 | 23 | 22 | 21 | 25 | 20 | | | |
| **Route 12** | Arrival time | 9.33 | 14.28 | 16.91 | 19.86 | 21.78 | 24.7 | 26.35 | 30.58 | 38.76 | 40.53 | 51.9 | 54.13 | 57.65 | 61.73 | 63.36 | 64.94 | | | |
| | Vehicle load | 14 | 26 | 38 | 50 | 62 | 78 | 89 | 100 | 110 | 124 | 135 | 146 | 160 | 173 | 185 | 198 | | | |
| | Nodes | 376 | 95 | 265 | 81 | 423 | 305 | 303 | 302 | 301 | 304 | 299 | 294 | 230 | 295 | 274 | 436 | 424 | | |
| **Route 13** | Arrival time | 9.42 | 11.52 | 15.24 | 28.01 | 37.49 | 41.94 | 44.76 | 48.31 | 51.23 | 55.26 | 59.84 | 61.57 | 62.69 | 65.06 | 68.79 | 68.79 | 71.67 | | |
| | Vehicle load | 11 | 23 | 35 | 44 | 55 | 68 | 81 | 88 | 103 | 118 | 128 | 141 | 154 | 167 | 178 | 186 | 199 | | |
| | Nodes | 97 | 98 | 99 | 149 | 148 | 146 | 150 | 165 | 193 | 288 | 194 | 133 | 134 | 135 | | | | | |
| **Route 14** | Arrival time | 9.65 | 9.65 | 11.5 | 36.58 | 40.16 | 41.58 | 49.85 | 53.58 | 56.65 | 64.1 | 67.12 | 76.25 | 76.25 | 76.25 | | | | | |
| | Vehicle load | 14 | 29 | 41 | 54 | 66 | 77 | 89 | 100 | 113 | 126 | 138 | 150 | 160 | 173 | | | | | |
| | Nodes | 92 | 14 | 16 | 26 | 17 | 15 | 19 | 18 | 27 | | | | | | | | | | |
| **Route 15** | Arrival time | 10.73 | 19.65 | 25.9 | 31.98 | 38.6 | 47.18 | 53.56 | 60.74 | 73.66 | | | | | | | | | | |
| | Vehicle load | 12 | 27 | 38 | 47 | 59 | 70 | 86 | 99 | 107 | | | | | | | | | | |
| | Nodes | 267 | 269 | 270 | 297 | 292 | 300 | 447 | 162 | 177 | 331 | 222 | 218 | 220 | 363 | 362 | | | | |
| **Route 16** | Arrival time | 10.95 | 15.87 | 18.59 | 29.84 | 36.52 | 39.09 | 47.62 | 50.47 | 55.95 | 62.98 | 69.8 | 73.57 | 73.57 | 78.44 | 79.22 | | | | |
| | Vehicle load | 11 | 23 | 35 | 47 | 59 | 72 | 83 | 97 | 107 | 117 | 129 | 141 | 154 | 163 | 178 | | | | |
| | Nodes | 266 | 268 | 298 | 293 | 296 | 439 | 430 | 428 | 425 | 427 | 68 | 63 | 429 | 65 | 67 | 69 | 448 | | |
| **Route 17** | Arrival time | 12.4 | 19.75 | 33.75 | 36.72 | 41.7 | 47.98 | 48.95 | 52.18 | 54.18 | 55.83 | 57.6 | 61.15 | 62.45 | 64.95 | 66.83 | 67.43 | 68.03 | | |
| | Vehicle load | 9 | 23 | 35 | 48 | 61 | 71 | 83 | 94 | 106 | 118 | 131 | 143 | 158 | 169 | 180 | 190 | 199 | | |
| | Nodes | 271 | 73 | 79 | 277 | 433 | 80 | 426 | 412 | 421 | 422 | 127 | 126 | 129 | 123 | 122 | | | | |
| **Route 18** | Arrival time | 12.43 | 20.38 | 20.73 | 24.11 | 26.93 | 27.15 | 36.55 | 39.43 | 40.43 | 45.96 | 57.69 | 59.51 | 59.51 | 59.71 | 60.64 | | | | |
| | Vehicle load | 14 | 27 | 40 | 53 | 67 | 79 | 89 | 104 | 119 | 133 | 147 | 158 | 171 | 184 | 197 | | | | |
| | Nodes | 420 | 353 | 58 | 59 | 139 | 60 | 354 | 36 | 31 | 32 | 62 | 61 | 71 | 72 | 66 | 234 | 276 | | |
| **Route 19** | Arrival time | 12.88 | 15.28 | 18.98 | 18.98 | 18.98 | 19.51 | 20.98 | 23.06 | 26.61 | 26.94 | 28.87 | 32.49 | 36.12 | 36.12 | 43.44 | 47.49 | 53.39 | | |
| | Vehicle load | 10 | 21 | 34 | 42 | 58 | 68 | 81 | 90 | 102 | 114 | 124 | 135 | 148 | 160 | 171 | 185 | 198 | | |
| | Nodes | 418 | 355 | 351 | 352 | 437 | 419 | 33 | 232 | 29 | 409 | 281 | 136 | 137 | | | | | | |
| **Route 20** | Arrival time | 14.75 | 19.45 | 24.13 | 26.76 | 30.04 | 33.76 | 41.94 | 48.49 | 50.51 | 56.16 | 65.84 | 75.94 | 77.12 | | | | | | |
| | Vehicle load | 11 | 22 | 32 | 44 | 54 | 69 | 80 | 94 | 104 | 116 | 130 | 137 | 147 | | | | | | |
| | Nodes | 40 | 39 | 41 | 42 | 43 | 37 | 38 | 416 | 417 | 414 | 415 | 413 | 12 | 48 | 45 | 47 | | | |
| **Route 21** | Arrival time | 15.3 | 18.78 | 21.23 | 26.43 | 29.61 | 30.49 | 31.11 | 39.43 | 41.36 | 44.96 | 48.89 | 57.27 | 67.3 | 73.83 | 77.26 | 79.03 | | | |
| | Vehicle load | 14 | 22 | 36 | 51 | 60 | 73 | 85 | 95 | 112 | 125 | 138 | 146 | 156 | 168 | 182 | 196 | | | |
| | Nodes | 35 | 227 | 228 | 438 | 229 | 231 | 224 | 44 | 243 | 46 | 34 | 170 | 286 | 287 | | | | | |
| **Route 22** | Arrival time | 15.75 | 22.3 | 24.93 | 26.9 | 29.8 | 33.43 | 36.45 | 45.1 | 54.48 | 58.1 | 70.05 | 73.15 | 76.17 | 77.5 | | | | | |
| | Vehicle load | 13 | 24 | 35 | 48 | 61 | 70 | 84 | 100 | 109 | 122 | 137 | 147 | 159 | 169 | | | | | |
| | Nodes | 347 | 344 | 343 | 195 | 233 | 340 | 341 | 342 | 339 | | | | | | | | | | |
| **Route 23** | Arrival time | 15.72 | 29.42 | 31.72 | 39.87 | 48.67 | 63.52 | 65.64 | 71.39 | 79.87 | | | | | | | | | | |
| | Vehicle load | 11 | 24 | 38 | 51 | 60 | 72 | 86 | 93 | 105 | | | | | | | | | | |
| | Nodes | 432 | 431 | 147 | 120 | 446 | 121 | 124 | 125 | 130 | 111 | 109 | 113 | 103 | 106 | | | | | |
| **Route 24** | Arrival time | 15.92 | 20.65 | 29.12 | 37.8 | 38.78 | 41.53 | 44.25 | 47.85 | 54.72 | 58.49 | 61.44 | 66.01 | 70.01 | 76.23 | | | | | |
| | Vehicle load | 9 | 19 | 33 | 43 | 55 | 63 | 73 | 86 | 96 | 106 | 118 | 129 | 137 | 146 | | | | | |
| | Nodes | 435 | 434 | 275 | 278 | 82 | 83 | 84 | 291 | 74 | 75 | 76 | 77 | 78 | 30 | 164 | 369 | | | |
| **Route 25** | Arrival time | 15.92 | 19.3 | 26.68 | 30.8 | 34.93 | 37.23 | 38.2 | 40.9 | 45.83 | 46.66 | 48.44 | 50.49 | 53.91 | 59.91 | 73.94 | 77.49 | | | |
| | Vehicle load | 12 | 25 | 39 | 52 | 64 | 75 | 85 | 98 | 109 | 124 | 134 | 145 | 158 | 169 | 179 | 195 | | | |

Table 27. Routing detail of Instance 5. Part 1.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 172 | 184 | 403 | 405 | 179 | 401 | 404 | | | | | | | | | |
| **Route 26** | Arrival time | 15.98 | 27.91 | 40.36 | 40.36 | 54.64 | 63.74 | 63.74 | | | | | | | | | |
| | Vehicle load | 9 | 20 | 32 | 45 | 57 | 72 | 84 | | | | | | | | | |
| | Nodes | 272 | 273 | 235 | 196 | 226 | 223 | 215 | 248 | 247 | 241 | 361 | 239 | 219 | 238 | 221 | 290 |
| **Route 27** | Arrival time | 16.2 | 17.38 | 22.96 | 29.24 | 35.16 | 44.54 | 50.07 | 51.39 | 53.56 | 55.96 | 57.49 | 59.51 | 62.38 | 62.38 | 67.13 | 71.21 |
| | Vehicle load | 14 | 30 | 41 | 57 | 69 | 77 | 88 | 100 | 112 | 125 | 133 | 142 | 155 | 167 | 181 | 195 |
| | Nodes | 211 | 208 | 201 | 199 | 205 | 203 | 198 | 197 | 209 | | | | | | | |
| **Route 28** | Arrival time | 16.63 | 30.18 | 40.46 | 44.38 | 47.98 | 55.08 | 59.58 | 62.06 | 72.18 | | | | | | | |
| | Vehicle load | 14 | 28 | 42 | 51 | 62 | 72 | 83 | 95 | 108 | | | | | | | |
| | Nodes | 56 | 411 | 410 | 52 | 51 | 50 | 57 | 55 | 53 | 138 | 171 | 163 | | | | |
| **Route 29** | Arrival time | 16.98 | 21.81 | 22.93 | 28.48 | 30.66 | 35.26 | 40.39 | 44.57 | 48.4 | 63.02 | 68.59 | 76.71 | | | | |
| | Vehicle load | 13 | 26 | 39 | 53 | 64 | 77 | 92 | 104 | 117 | 129 | 142 | 153 | | | | |
| | Nodes | 346 | 225 | 345 | 49 | 338 | 174 | | | | | | | | | | |
| **Route 30** | Arrival time | 17.78 | 20.45 | 24.92 | 35.82 | 51.52 | 78.87 | | | | | | | | | | |
| | Vehicle load | 14 | 22 | 37 | 49 | 61 | 72 | | | | | | | | | | |
| | Nodes | 54 | 186 | 240 | 214 | 242 | 244 | 367 | 249 | 365 | 237 | 442 | 216 | 217 | 366 | 441 | 236 |
| **Route 31** | Arrival time | 19.33 | 33.75 | 40 | 47.92 | 57.07 | 59.25 | 63.33 | 63.63 | 65.53 | 67.45 | 69.33 | 72.01 | 72.01 | 74.83 | 76.33 | 78.86 |
| | Vehicle load | 13 | 25 | 40 | 53 | 67 | 82 | 95 | 105 | 115 | 125 | 132 | 147 | 159 | 171 | 183 | 193 |
| | Nodes | 394 | 116 | 115 | 118 | 100 | 101 | 102 | 112 | 392 | 110 | 395 | 393 | 117 | | | |
| **Route 32** | Arrival time | 20.27 | 24.42 | 26.47 | 27.77 | 32.24 | 38.77 | 38.77 | 42.84 | 46.52 | 55.79 | 62.07 | 67.44 | 79.32 | | | |
| | Vehicle load | 8 | 20 | 33 | 44 | 56 | 67 | 80 | 89 | 99 | 113 | 127 | 140 | 150 | | | |
| | Nodes | 368 | 443 | 357 | 213 | 360 | 245 | 246 | 212 | 358 | 359 | 191 | | | | | |
| **Route 33** | Arrival time | 21.88 | 27.61 | 29.43 | 32.86 | 34.11 | 38.14 | 39.07 | 41.35 | 42.88 | 43.16 | 56.98 | | | | | |
| | Vehicle load | 10 | 22 | 33 | 44 | 59 | 71 | 82 | 96 | 108 | 122 | 132 | | | | | |
| | Nodes | 114 | 397 | 64 | | | | | | | | | | | | | |
| **Route 34** | Arrival time | 22.47 | 46.07 | 70.17 | | | | | | | | | | | | | |
| | Vehicle load | 11 | 24 | 42 | | | | | | | | | | | | | |
| | Nodes | 173 | | | | | | | | | | | | | | | |
| **Route 35** | Arrival time | 19.87 | | | | | | | | | | | | | | | |
| | Vehicle load | 10 | | | | | | | | | | | | | | | |

Table 28. Routing detail of Instance 5. Part 2.

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 1 | 156 | 105 | 108 | 107 | | | | | | | | | | | | |
| **Route 1** | Arrival time | 25 | 40.1 | 47.88 | 49.1 | 54.68 | | | | | | | | | | | | |
| | Vehicle load | 9 | 20 | 34 | 43 | 54 | | | | | | | | | | | | |
| | Nodes | 306 | 280 | 318 | 319 | 184 | | | | | | | | | | | | |
| **Route 2** | Arrival time | 25 | 29.08 | 30.45 | 38.35 | 54.9 | | | | | | | | | | | | |
| | Vehicle load | 10 | 25 | 36 | 49 | 60 | | | | | | | | | | | | |
| | Nodes | 279 | 317 | 311 | 316 | 315 | 91 | 372 | | | | | | | | | | |
| **Route 3** | Arrival time | 25 | 31.23 | 34.4 | 37.1 | 40.3 | 45.48 | 53.01 | | | | | | | | | | |
| | Vehicle load | 15 | 29 | 42 | 54 | 67 | 79 | 91 | | | | | | | | | | |
| | Nodes | 320 | 325 | 326 | 329 | 330 | 323 | 327 | 322 | 321 | | | | | | | | |
| **Route 4** | Arrival time | 25 | 37.8 | 37.8 | 40.38 | 43.95 | 46.78 | 49.53 | 50.96 | 53.88 | | | | | | | | |
| | Vehicle load | 11 | 25 | 37 | 49 | 64 | 72 | 86 | 100 | 113 | | | | | | | | |
| | Nodes | 348 | 406 | 263 | 262 | 261 | 356 | 445 | 444 | 250 | 251 | 257 | 258 | 252 | | | | |
| **Route 5** | Arrival time | 25 | 27.42 | 29.65 | 33.4 | 34.38 | 38.11 | 41.73 | 44.15 | 46.07 | 47.35 | 48.47 | 51.32 | 53.94 | | | | |
| | Vehicle load | 11 | 23 | 36 | 47 | 59 | 69 | 81 | 94 | 107 | 120 | 130 | 144 | 157 | | | | |
| | Nodes | 314 | 312 | 313 | 449 | 371 | 375 | | | | | | | | | | | |
| **Route 6** | Arrival time | 25 | 27.72 | 31.07 | 40.87 | 48.39 | 53.26 | | | | | | | | | | | |
| | Vehicle load | 12 | 26 | 40 | 52 | 62 | 73 | | | | | | | | | | | |
| | Nodes | 407 | 190 | 189 | | | | | | | | | | | | | | |
| **Route 7** | Arrival time | 25 | 50.93 | 53.5 | | | | | | | | | | | | | | |
| | Vehicle load | 17 | 30 | 41 | | | | | | | | | | | | | | |
| | Nodes | 408 | 259 | 255 | 254 | 256 | 6 | 260 | | | | | | | | | | |
| **Route 8** | Arrival time | 25 | 31.37 | 39.44 | 41.36 | 44.04 | 49.46 | 54.44 | | | | | | | | | | |
| | Vehicle load | 13 | 27 | 40 | 53 | 65 | 78 | 89 | | | | | | | | | | |
| | Nodes | 11 | 13 | 8 | 9 | 7 | 10 | 210 | | | | | | | | | | |
| **Route 9** | Arrival time | 25 | 26.88 | 35.16 | 36.84 | 38.41 | 38.41 | 51.13 | | | | | | | | | | |
| | Vehicle load | 9 | 21 | 33 | 48 | 62 | 78 | 93 | | | | | | | | | | |
| | Nodes | 333 | 324 | 328 | 332 | | | | | | | | | | | | | |
| **Route 10** | Arrival time | 25 | 37.08 | 38.46 | 44.99 | | | | | | | | | | | | | |
| | Vehicle load | 15 | 27 | 39 | 50 | | | | | | | | | | | | | |
| | Nodes | 349 | 350 | 128 | 158 | 159 | | | | | | | | | | | | |
| **Route 11** | Arrival time | 25 | 25 | 52.15 | 52.15 | 53.28 | | | | | | | | | | | | |
| | Vehicle load | 13 | 25 | 35 | 47 | 59 | | | | | | | | | | | | |
| | Nodes | 3 | 2 | 5 | 253 | 264 | 418 | | | | | | | | | | | |
| **Route 12** | Arrival time | 25 | 25.65 | 27.62 | 35.75 | 41.13 | 53.01 | | | | | | | | | | | |
| | Vehicle load | 10 | 23 | 33 | 46 | 57 | 68 | | | | | | | | | | | |
| | Nodes | 4 | 42 | 43 | 37 | 38 | 41 | | | | | | | | | | | |
| **Route 13** | Arrival time | 25 | 42.55 | 45.73 | 46.61 | 47.23 | 53.33 | | | | | | | | | | | |
| | Vehicle load | 9 | 24 | 33 | 46 | 58 | 72 | | | | | | | | | | | |
| | Nodes | 94 | 85 | 86 | 308 | 385 | 384 | 307 | 93 | | | | | | | | | |
| **Route 14** | Arrival time | 25 | 35.02 | 36.04 | 39.22 | 42.4 | 45.38 | 49.06 | 54.91 | | | | | | | | | |
| | Vehicle load | 14 | 25 | 34 | 46 | 57 | 69 | 81 | 93 | | | | | | | | | |
| | Nodes | 376 | 95 | 265 | 450 | 396 | | | | | | | | | | | | |
| **Route 15** | Arrival time | 25 | 27.1 | 30.82 | 52.05 | 53.72 | | | | | | | | | | | | |
| | Vehicle load | 11 | 23 | 35 | 49 | 65 | | | | | | | | | | | | |
| | Nodes | 97 | 98 | 99 | 90 | 377 | 378 | 379 | 380 | 88 | 87 | 382 | 383 | | | | | |
| **Route 16** | Arrival time | 25 | 25 | 26.85 | 32.42 | 33.19 | 38.62 | 42.5 | 44.15 | 47.7 | 49.13 | 50.33 | 53.28 | | | | | |
| | Vehicle load | 14 | 29 | 41 | 56 | 68 | 79 | 95 | 106 | 118 | 129 | 141 | 153 | | | | | |
| | Nodes | 96 | 374 | 373 | 370 | 81 | 277 | | | | | | | | | | | |
| **Route 17** | Arrival time | 25 | 30.48 | 31.26 | 34.91 | 52.93 | 54.38 | | | | | | | | | | | |
| | Vehicle load | 14 | 24 | 36 | 44 | 53 | 66 | | | | | | | | | | | |
| | Nodes | 92 | 14 | 16 | 24 | 23 | | | | | | | | | | | | |
| **Route 18** | Arrival time | 25 | 33.92 | 40.17 | 50.52 | 52.75 | | | | | | | | | | | | |
| | Vehicle load | 12 | 27 | 38 | 49 | 60 | | | | | | | | | | | | |
| | Nodes | 267 | 269 | 270 | 297 | 292 | 230 | 295 | | | | | | | | | | |
| **Route 19** | Arrival time | 25 | 29.92 | 32.64 | 43.89 | 50.57 | 51.8 | 54.17 | | | | | | | | | | |
| | Vehicle load | 11 | 23 | 35 | 47 | 59 | 72 | 85 | | | | | | | | | | |
| | Nodes | 381 | 268 | 298 | 274 | 436 | 424 | | | | | | | | | | | |
| **Route 20** | Arrival time | 25 | 32.63 | 46.63 | 51.8 | 51.8 | 54.68 | | | | | | | | | | | |
| | Vehicle load | 12 | 26 | 38 | 49 | 57 | 70 | | | | | | | | | | | |
| | Nodes | 266 | 390 | 389 | 154 | | | | | | | | | | | | | |
| **Route 21** | Arrival time | 25 | 52.65 | 53.02 | 54.72 | | | | | | | | | | | | | |
| | Vehicle load | 9 | 19 | 28 | 39 | | | | | | | | | | | | | |
| | Nodes | 271 | 68 | 439 | 430 | 428 | 425 | 427 | 426 | | | | | | | | | |
| **Route 22** | Arrival time | 25 | 39.55 | 42.1 | 43.07 | 46.3 | 48.3 | 49.95 | 53.83 | | | | | | | | | |
| | Vehicle load | 14 | 27 | 37 | 49 | 60 | 72 | 84 | 94 | | | | | | | | | |
| | Nodes | 310 | 309 | 20 | 21 | 22 | 25 | 17 | | | | | | | | | | |
| **Route 23** | Arrival time | 25 | 26.77 | 35.85 | 37.52 | 41.55 | 46.87 | 51.32 | | | | | | | | | | |
| | Vehicle load | 14 | 24 | 37 | 50 | 64 | 76 | 88 | | | | | | | | | | |
| | Nodes | 420 | 353 | 58 | 59 | 139 | 60 | 354 | 36 | 31 | 32 | 62 | 61 | 71 | 72 | 84 | 83 | |
| **Route 24** | Arrival time | 25 | 27.4 | 31.1 | 31.1 | 31.1 | 31.63 | 33.1 | 35.18 | 38.73 | 39.06 | 40.99 | 44.61 | 48.24 | 48.24 | 53.97 | 54.94 | |
| | Vehicle load | 10 | 21 | 34 | 42 | 58 | 68 | 81 | 90 | 102 | 114 | 124 | 135 | 148 | 160 | 170 | 181 | |
| | Nodes | 15 | 26 | 27 | 28 | | | | | | | | | | | | | |
| **Route 25** | Arrival time | 25 | 33.07 | 39.57 | 47.6 | | | | | | | | | | | | | |
| | Vehicle load | 11 | 20 | 28 | 40 | | | | | | | | | | | | | |

Table 29. Routing detail of Instance 6. Part 1.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 19 | 18 | 118 | | | | | | | | | |
| **Route 26** | Arrival time | 25 | 32.18 | 54.98 | | | | | | | | | |
| | Vehicle load | 16 | 29 | 40 | | | | | | | | | |
| | Nodes | 419 | 437 | 352 | 351 | 355 | 75 | 76 | 77 | | | | |
| **Route 27** | Arrival time | 25 | 29.07 | 31.92 | 34.55 | 39.35 | 48.55 | 50.33 | 52.38 | | | | |
| | Vehicle load | 15 | 25 | 37 | 47 | 58 | 73 | 83 | 94 | | | | |
| | Nodes | 40 | 39 | 415 | 417 | 416 | 414 | 413 | | | | | |
| **Route 28** | Arrival time | 25 | 28.48 | 33.33 | 37.31 | 39.39 | 42.74 | 48.79 | | | | | |
| | Vehicle load | 14 | 22 | 35 | 52 | 62 | 75 | 83 | | | | | |
| | Nodes | 35 | 33 | 232 | 29 | 63 | 429 | 65 | 67 | 69 | 66 | 448 | 291 |
| **Route 29** | Arrival time | 25 | 29.7 | 36.25 | 38.27 | 43.69 | 44.99 | 47.49 | 49.37 | 49.97 | 50.07 | 50.57 | 54.47 |
| | Vehicle load | 13 | 24 | 38 | 48 | 60 | 75 | 86 | 97 | 107 | 118 | 127 | 140 |
| | Nodes | 347 | 89 | | | | | | | | | | |
| **Route 30** | Arrival time | 25 | 54.25 | | | | | | | | | | |
| | Vehicle load | 11 | 23 | | | | | | | | | | |
| | Nodes | 432 | 423 | 305 | 303 | 302 | 301 | 304 | | | | | |
| **Route 31** | Arrival time | 25 | 37.02 | 41.47 | 44.29 | 47.84 | 50.76 | 54.79 | | | | | |
| | Vehicle load | 9 | 20 | 33 | 46 | 53 | 68 | 83 | | | | | |
| | Nodes | 435 | 434 | 433 | 80 | 73 | 79 | 82 | 422 | 299 | 294 | | |
| **Route 32** | Arrival time | 25 | 28.38 | 32.16 | 32.38 | 33.78 | 34.13 | 36.43 | 46.01 | 50.33 | 52.06 | | |
| | Vehicle load | 12 | 25 | 39 | 51 | 64 | 77 | 89 | 103 | 113 | 126 | | |
| | Nodes | 172 | 182 | 180 | 181 | 183 | | | | | | | |
| **Route 33** | Arrival time | 25 | 38.3 | 42.07 | 44.17 | 49.62 | | | | | | | |
| | Vehicle load | 9 | 22 | 32 | 46 | 59 | | | | | | | |
| | Nodes | 272 | 273 | 275 | 296 | 300 | | | | | | | |
| **Route 34** | Arrival time | 25 | 26.18 | 34.43 | 42.8 | 50.12 | | | | | | | |
| | Vehicle load | 14 | 30 | 44 | 57 | 70 | | | | | | | |
| | Nodes | 211 | 207 | 206 | 204 | 202 | 200 | 201 | 199 | 205 | | | |
| **Route 35** | Arrival time | 25 | 36.97 | 38.77 | 41.85 | 42.27 | 45.07 | 46.17 | 50.09 | 53.69 | | | |
| | Vehicle load | 14 | 28 | 39 | 48 | 60 | 76 | 90 | 99 | 110 | | | |
| | Nodes | 56 | 411 | 48 | 45 | 47 | 44 | 243 | | | | | |
| **Route 36** | Arrival time | 25 | 29.83 | 32.33 | 35.76 | 37.53 | 44.55 | 53.93 | | | | | |
| | Vehicle load | 13 | 26 | 38 | 52 | 66 | 82 | 91 | | | | | |
| | Nodes | 78 | 30 | 234 | 421 | 412 | 409 | 164 | | | | | |
| **Route 37** | Arrival time | 25 | 31 | 33.7 | 40.13 | 43.58 | 46.98 | 54.43 | | | | | |
| | Vehicle load | 13 | 24 | 38 | 53 | 68 | 80 | 90 | | | | | |
| | Nodes | 278 | 276 | 149 | 148 | 146 | 150 | | | | | | |
| **Route 38** | Arrival time | 25 | 31.05 | 41.25 | 44.83 | 46.25 | 54.52 | | | | | | |
| | Vehicle load | 13 | 26 | 39 | 51 | 62 | 74 | | | | | | |
| | Nodes | 235 | 227 | 228 | 438 | 229 | 231 | 224 | 12 | | | | |
| **Route 39** | Arrival time | 25 | 27.95 | 30.58 | 32.55 | 35.45 | 39.08 | 42.1 | 52.57 | | | | |
| | Vehicle load | 11 | 22 | 33 | 46 | 59 | 68 | 82 | 92 | | | | |
| | Nodes | 346 | 225 | 345 | 344 | 343 | 195 | 54 | | | | | |
| **Route 40** | Arrival time | 25 | 27.67 | 32.14 | 37.81 | 40.11 | 48.26 | 53.18 | | | | | |
| | Vehicle load | 14 | 22 | 37 | 50 | 64 | 77 | 90 | | | | | |
| | Nodes | 196 | 226 | 223 | 46 | 410 | | | | | | | |
| **Route 41** | Arrival time | 25 | 30.92 | 40.3 | 47.45 | 54.15 | | | | | | | |
| | Vehicle load | 16 | 28 | 36 | 49 | 62 | | | | | | | |
| | Nodes | 74 | 431 | 152 | 119 | | | | | | | | |
| **Route 42** | Arrival time | 25 | 36.2 | 50.45 | 52.35 | | | | | | | | |
| | Vehicle load | 11 | 21 | 29 | 43 | | | | | | | | |
| | Nodes | 57 | 55 | 53 | 52 | 145 | 70 | 138 | 140 | | | | |
| **Route 43** | Arrival time | 25 | 29.18 | 33.01 | 38.01 | 51.53 | 51.7 | 53.68 | 54.65 | | | | |
| | Vehicle load | 15 | 27 | 40 | 54 | 66 | 77 | 89 | 105 | | | | |
| | Nodes | 394 | 116 | 115 | 100 | 106 | 391 | 155 | | | | | |
| **Route 44** | Arrival time | 25 | 29.15 | 31.2 | 35.25 | 45.12 | 49.24 | 52.26 | | | | | |
| | Vehicle load | 8 | 20 | 33 | 45 | 54 | 66 | 76 | | | | | |
| | Nodes | 403 | 405 | 179 | 399 | 400 | 398 | 401 | 402 | 404 | | | |
| **Route 45** | Arrival time | 25 | 25 | 39.28 | 46.95 | 46.95 | 48.38 | 48.38 | 48.38 | 48.38 | | | |
| | Vehicle load | 12 | 25 | 37 | 49 | 62 | 76 | 91 | 104 | 116 | | | |
| | Nodes | 197 | 203 | 334 | 335 | | | | | | | | |
| **Route 46** | Arrival time | 25 | 31.02 | 41.57 | 51.45 | | | | | | | | |
| | Vehicle load | 12 | 22 | 32 | 42 | | | | | | | | |
| | Nodes | 51 | 50 | 214 | | | | | | | | | |
| **Route 47** | Arrival time | 25 | 29.6 | 49.23 | | | | | | | | | |
| | Vehicle load | 11 | 24 | 37 | | | | | | | | | |
| | Nodes | 209 | 208 | 336 | | | | | | | | | |
| **Route 48** | Arrival time | 25 | 39.4 | 54 | | | | | | | | | |
| | Vehicle load | 13 | 27 | 38 | | | | | | | | | |
| | Nodes | 368 | 369 | 161 | 440 | 364 | 185 | 187 | 188 | 160 | | | |
| **Route 49** | Arrival time | 25 | 27.87 | 35.55 | 38.15 | 41.22 | 43.92 | 47.32 | 50.24 | 51.81 | | | |
| | Vehicle load | 10 | 26 | 38 | 50 | 61 | 75 | 85 | 98 | 110 | | | |
| | Nodes | 49 | 233 | 340 | 341 | 342 | | | | | | | |
| **Route 50** | Arrival time | 25 | 31.55 | 46.4 | 48.52 | 54.27 | | | | | | | |
| | Vehicle load | 12 | 21 | 33 | 47 | 54 | | | | | | | |

Table 30. Routing detail of Instance 6. Part 2.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 236 | 248 | 247 | 241 | 361 | 222 | 218 | 220 | 363 | 362 | 186 | | | |
| **Route 51** | Arrival time | 25 | 28.98 | 31.15 | 33.55 | 35.08 | 41.63 | 45.4 | 45.4 | 50.27 | 51.05 | 54.23 | | | |
| | Vehicle load | 10 | 22 | 34 | 47 | 55 | 67 | 79 | 92 | 101 | 116 | 128 | | | |
| | Nodes | 395 | 110 | 130 | 446 | 120 | 121 | 122 | 126 | 129 | 127 | 123 | 124 | | |
| **Route 52** | Arrival time | 25 | 32.93 | 37.96 | 41.58 | 42.56 | 44.34 | 45.04 | 46.06 | 46.06 | 47.86 | 49.86 | 52.69 | | |
| | Vehicle load | 14 | 28 | 38 | 50 | 60 | 68 | 81 | 92 | 105 | 119 | 132 | 142 | | |
| | Nodes | 114 | 111 | 109 | 387 | 153 | 388 | 386 | | | | | | | |
| **Route 53** | Arrival time | 25 | 41.87 | 44.82 | 53.35 | 53.68 | 53.68 | 54.13 | | | | | | | |
| | Vehicle load | 11 | 21 | 33 | 45 | 53 | 63 | 76 | | | | | | | |
| | Nodes | 358 | 359 | 215 | 249 | 365 | 237 | 442 | 216 | 217 | 284 | 285 | 282 | 143 | 169 |
| **Route 54** | Arrival time | 25 | 25.28 | 27.93 | 29.51 | 31.41 | 33.33 | 35.21 | 37.89 | 37.89 | 44.97 | 44.97 | 46.09 | 50.97 | 52.57 |
| | Vehicle load | 12 | 26 | 37 | 47 | 57 | 67 | 74 | 89 | 101 | 111 | 127 | 142 | 151 | 163 |
| | Nodes | 357 | 443 | 367 | 239 | 219 | 238 | 221 | 290 | 240 | | | | | |
| **Route 55** | Arrival time | 25 | 27.43 | 34.13 | 38.56 | 41.43 | 41.43 | 46.18 | 50.26 | 53.83 | | | | | |
| | Vehicle load | 11 | 23 | 36 | 45 | 58 | 70 | 84 | 98 | 113 | | | | | |
| | Nodes | 212 | 245 | 246 | 213 | 360 | 244 | 242 | 34 | 170 | 136 | | | | |
| **Route 56** | Arrival time | 25 | 29.47 | 30.4 | 32.48 | 33.73 | 34.96 | 36.43 | 47.5 | 50.6 | 54.73 | | | | |
| | Vehicle load | 14 | 26 | 37 | 48 | 63 | 78 | 92 | 107 | 117 | 124 | | | | |
| | Nodes | 441 | 366 | 447 | 166 | 168 | 192 | 167 | 144 | 141 | 133 | 134 | 135 | | |
| **Route 57** | Arrival time | 25 | 27.37 | 34.64 | 35.54 | 40.21 | 42.23 | 42.71 | 45.58 | 48.5 | 53.73 | 53.73 | 53.73 | | |
| | Vehicle load | 12 | 24 | 35 | 46 | 55 | 64 | 73 | 81 | 87 | 99 | 109 | 122 | | |
| | Nodes | 393 | 101 | 102 | 103 | 113 | 112 | 392 | | | | | | | |
| **Route 58** | Arrival time | 25 | 30.45 | 30.45 | 33.3 | 39.12 | 41.99 | 45.67 | | | | | | | |
| | Vehicle load | 13 | 24 | 37 | 45 | 56 | 65 | 75 | | | | | | | |
| | Nodes | 198 | 338 | 339 | | | | | | | | | | | |
| **Route 59** | Arrival time | 25 | 40.98 | 50.48 | | | | | | | | | | | |
| | Vehicle load | 11 | 23 | 35 | | | | | | | | | | | |
| | Nodes | 174 | 178 | 175 | 176 | | | | | | | | | | |
| **Route 60** | Arrival time | 25.52 | 44.37 | 50.05 | 50.05 | | | | | | | | | | |
| | Vehicle load | 11 | 25 | 38 | 50 | | | | | | | | | | |
| | Nodes | 125 | 157 | 151 | 193 | 165 | 194 | | | | | | | | |
| **Route 61** | Arrival time | 25.37 | 40.07 | 45.05 | 48.68 | 51.41 | 54.39 | | | | | | | | |
| | Vehicle load | 13 | 24 | 36 | 49 | 60 | 72 | | | | | | | | |
| | Nodes | 293 | 131 | 132 | 283 | 142 | 137 | 286 | 287 | | | | | | |
| **Route 62** | Arrival time | 25.63 | 36.21 | 36.66 | 37.58 | 41.78 | 45.25 | 51.97 | 53.3 | | | | | | |
| | Vehicle load | 13 | 26 | 38 | 45 | 55 | 65 | 77 | 87 | | | | | | |
| | Nodes | 147 | 331 | 171 | | | | | | | | | | | |
| **Route 63** | Arrival time | 25.82 | 42.89 | 51.46 | | | | | | | | | | | |
| | Vehicle load | 14 | 24 | 37 | | | | | | | | | | | |
| | Nodes | 173 | 337 | | | | | | | | | | | | |
| **Route 64** | Arrival time | 25 | 48.4 | | | | | | | | | | | | |
| | Vehicle load | 10 | 21 | | | | | | | | | | | | |
| | Nodes | 281 | 162 | 288 | 177 | 163 | | | | | | | | | |
| **Route 65** | Arrival time | 27.83 | 29.83 | 37.73 | 42.38 | 50.75 | | | | | | | | | |
| | Vehicle load | 14 | 28 | 41 | 51 | 62 | | | | | | | | | |
| | Nodes | 289 | 191 | | | | | | | | | | | | |
| **Route 66** | Arrival time | 29.37 | 36.07 | | | | | | | | | | | | |
| | Vehicle load | 12 | 22 | | | | | | | | | | | | |
| | Nodes | 117 | 397 | 104 | | | | | | | | | | | |
| **Route 67** | Arrival time | 29.43 | 38.4 | 48.43 | | | | | | | | | | | |
| | Vehicle load | 10 | 23 | 33 | | | | | | | | | | | |
| | Nodes | 64 | | | | | | | | | | | | | |
| **Route 68** | Arrival time | 33.07 | | | | | | | | | | | | | |
| | Vehicle load | 18 | | | | | | | | | | | | | |

Table 31. Routing detail of Instance 6. Part 3.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 1 | 156 | 105 | 108 | 390 | 389 | 154 | 387 | 153 | 388 | 386 | 157 | | | | |
| **Route 1** | Arrival time | 78.22 | 43.71 | 51.49 | 56.67 | 43.08 | 43.45 | 66.44 | 67.41 | 39.73 | 39.73 | 60.77 | 58.17 | | | | |
| | Vehicle load | 121 | 43 | 57 | 104 | 53 | 62 | 146 | 158 | 33 | 43 | 84 | 127 | | | | |
| | Nodes | 306 | 280 | 318 | 319 | 180 | 181 | | | | | | | | | | |
| **Route 2** | Arrival time | 22.94 | 18.86 | 17.51 | 19.58 | 58.42 | 60.52 | | | | | | | | | | |
| | Vehicle load | 47 | 37 | 22 | 27 | 62 | 76 | | | | | | | | | | |
| | Nodes | 279 | 317 | 311 | 316 | 315 | 91 | 372 | 375 | 370 | 374 | 373 | | | | | |
| **Route 3** | Arrival time | 25.89 | 23.06 | 20.58 | 26.08 | 13.5 | 29.91 | 20.88 | 15.28 | 12.7 | 45.11 | 45.89 | | | | | |
| | Vehicle load | 62 | 54 | 40 | 66 | 27 | 78 | 31 | 19 | 8 | 84 | 96 | | | | | |
| | Nodes | 320 | 325 | 326 | 329 | 330 | 323 | 327 | 322 | 321 | 332 | 324 | 328 | | | | |
| **Route 4** | Arrival time | 9.66 | 18.2 | 26.28 | 15.85 | 28.81 | 22.38 | 31.76 | 33.19 | 36.11 | 39.61 | 44.83 | 46.21 | | | | |
| | Vehicle load | 11 | 26 | 46 | 12 | 61 | 34 | 75 | 89 | 102 | 113 | 125 | 137 | | | | |
| | Nodes | 348 | 406 | 263 | 262 | 261 | 356 | 445 | 444 | 190 | 189 | | | | | | |
| **Route 5** | Arrival time | 38.66 | 68.31 | 36.11 | 13.7 | 40.91 | 17.02 | 24.02 | 38.18 | 33.2 | 35.77 | | | | | | |
| | Vehicle load | 50 | 125 | 55 | 20 | 67 | 30 | 53 | 75 | 24 | 35 | | | | | | |
| | Nodes | 314 | 312 | 313 | 449 | 371 | 90 | 377 | 93 | 307 | | | | | | | |
| **Route 6** | Arrival time | 33.19 | 7.23 | 9.03 | 8.92 | 24.36 | 30.49 | 31.26 | 43.48 | 37.63 | | | | | | | |
| | Vehicle load | 74 | 14 | 14 | 12 | 41 | 56 | 68 | 94 | 82 | | | | | | | |
| | Nodes | 407 | 4 | 2 | 5 | 3 | 253 | 6 | 255 | 254 | 256 | | | | | | |
| **Route 7** | Arrival time | 34.23 | 32.04 | 24.87 | 26.84 | 29.17 | 46.14 | 26.63 | 30.18 | 18.53 | 21.21 | | | | | | |
| | Vehicle load | 39 | 42 | 13 | 23 | 33 | 80 | 49 | 62 | 24 | 36 | | | | | | |
| | Nodes | 408 | 259 | 252 | 251 | 250 | 257 | 128 | 158 | 159 | | | | | | | |
| **Route 8** | Arrival time | 29.33 | 53.84 | 50.86 | 41.38 | 40.1 | 42.5 | 45.56 | 45.56 | 73.78 | | | | | | | |
| | Vehicle load | 22 | 87 | 73 | 101 | 88 | 111 | 31 | 43 | 170 | | | | | | | |
| | Nodes | 11 | 13 | 8 | 9 | 7 | 10 | 210 | 207 | 206 | | | | | | | |
| **Route 9** | Arrival time | 7.42 | 29.67 | 54.5 | 52.82 | 56.57 | 14.63 | 27.35 | 26.88 | 28.68 | | | | | | | |
| | Vehicle load | 9 | 12 | 107 | 95 | 121 | 16 | 31 | 14 | 25 | | | | | | | |
| | Nodes | 333 | 183 | 182 | | | | | | | | | | | | | |
| **Route 10** | Arrival time | 47.74 | 41.21 | 54.65 | | | | | | | | | | | | | |
| | Vehicle load | 65 | 40 | 52 | | | | | | | | | | | | | |
| | Nodes | 349 | 350 | 258 | 89 | | | | | | | | | | | | |
| **Route 11** | Arrival time | 71.73 | 61.99 | 56.99 | 44.25 | | | | | | | | | | | | |
| | Vehicle load | 62 | 113 | 101 | 25 | | | | | | | | | | | | |
| | Nodes | 94 | 85 | 86 | 308 | 385 | 384 | 28 | 27 | | | | | | | | |
| **Route 12** | Arrival time | 16.01 | 18.41 | 17.43 | 22.61 | 30.97 | 33.95 | 53.5 | 45.87 | | | | | | | | |
| | Vehicle load | 14 | 20 | 9 | 32 | 58 | 70 | 118 | 56 | | | | | | | | |
| | Nodes | 376 | 95 | 265 | 450 | 396 | 109 | | | | | | | | | | |
| **Route 13** | Arrival time | 66.3 | 20.54 | 24.26 | 60.41 | 26.28 | 30.73 | | | | | | | | | | |
| | Vehicle load | 146 | 26 | 38 | 104 | 16 | 22 | | | | | | | | | | |
| | Nodes | 97 | 98 | 99 | 378 | 379 | 380 | 88 | 87 | 382 | 383 | 381 | 269 | 270 | | | |
| **Route 14** | Arrival time | 70.29 | 51.87 | 53.72 | 36.69 | 40.57 | 12.75 | 20.67 | 44.3 | 23.3 | 17.27 | 59.17 | 64.37 | 19.01 | | | |
| | Vehicle load | 55 | 111 | 123 | 79 | 95 | 11 | 35 | 106 | 47 | 23 | 135 | 176 | 26 | | | |
| | Nodes | 96 | 268 | 104 | 155 | 391 | | | | | | | | | | | |
| **Route 15** | Arrival time | 86.97 | 24.39 | 47.36 | 51.1 | 46.07 | | | | | | | | | | | |
| | Vehicle load | 191 | 40 | 50 | 95 | 74 | | | | | | | | | | | |
| | Nodes | 92 | 14 | 16 | 24 | 23 | 22 | 21 | 25 | 20 | | | | | | | |
| **Route 16** | Arrival time | 37.04 | 70.48 | 16.94 | 28.32 | 30.55 | 34.07 | 61.53 | 63.16 | 59.86 | | | | | | | |
| | Vehicle load | 90 | 133 | 22 | 23 | 34 | 48 | 144 | 156 | 131 | | | | | | | |
| | Nodes | 264 | 260 | 418 | 60 | 58 | 59 | 139 | 354 | 36 | 31 | 32 | 62 | 61 | 71 | 72 | 84 |
| **Route 17** | Arrival time | 10.9 | 20.74 | 31.97 | 23.83 | 24.36 | 26.26 | 24.36 | 25.31 | 27.81 | 53.37 | 53.7 | 55.63 | 59.25 | 44.22 | 62.88 | 39.3 |
| | Vehicle load | 11 | 41 | 64 | 31 | 44 | 81 | 60 | 73 | 90 | 123 | 135 | 145 | 156 | 120 | 168 | 94 |
| | Nodes | 267 | 81 | 423 | 305 | 303 | 302 | 301 | 304 | | | | | | | | |
| **Route 18** | Arrival time | 72.12 | 34.11 | 31.68 | 36.13 | 38.95 | 42.5 | 45.42 | 49.45 | | | | | | | | |
| | Vehicle load | 187 | 60 | 36 | 49 | 62 | 69 | 84 | 99 | | | | | | | | |
| | Nodes | 266 | 149 | 148 | 146 | 151 | 150 | | | | | | | | | | |
| **Route 19** | Arrival time | 18.76 | 38.23 | 52.34 | 41 | 54.49 | 36.3 | | | | | | | | | | |
| | Vehicle load | 9 | 66 | 55 | 77 | 116 | 25 | | | | | | | | | | |
| | Nodes | 271 | 68 | 439 | 430 | 428 | 425 | 427 | 426 | 412 | 421 | 422 | | | | | |
| **Route 20** | Arrival time | 12.43 | 31.13 | 52.99 | 53.96 | 57.19 | 51.96 | 60.84 | 71.7 | 55.36 | 65.28 | 27.56 | | | | | |
| | Vehicle load | 14 | 52 | 120 | 132 | 143 | 180 | 155 | 160 | 195 | 150 | 53 | | | | | |
| | Nodes | 310 | 309 | 26 | 17 | 15 | 19 | 18 | | | | | | | | | |
| **Route 21** | Arrival time | 49.01 | 50.78 | 77.96 | 67.61 | 14.02 | 56.05 | 63.23 | | | | | | | | | |
| | Vehicle load | 108 | 118 | 177 | 168 | 11 | 72 | 85 | | | | | | | | | |
| | Nodes | 420 | 353 | 352 | 351 | 355 | 75 | 76 | 77 | 78 | 63 | | | | | | |
| **Route 22** | Arrival time | 12.88 | 71.15 | 40.81 | 38.18 | 18.03 | 37.62 | 39.4 | 41.45 | 44.87 | 44.38 | | | | | | |
| | Vehicle load | 10 | 162 | 60 | 48 | 21 | 79 | 89 | 100 | 113 | 139 | | | | | | |
| | Nodes | 419 | 437 | 33 | 232 | 29 | 429 | 65 | 67 | 69 | 66 | 448 | 234 | | | | |
| **Route 23** | Arrival time | 57.96 | 62.03 | 19.53 | 36.94 | 38.96 | 45.68 | 66.07 | 35.43 | 36.03 | 67.45 | 77.17 | 47.16 | | | | |
| | Vehicle load | 60 | 70 | 11 | 117 | 127 | 154 | 166 | 63 | 73 | 177 | 169 | 168 | | | | |
| | Nodes | 40 | 39 | 41 | 42 | 43 | 37 | 38 | 416 | 417 | 414 | 415 | | | | | |
| **Route 24** | Arrival time | 84.42 | 17.53 | 49.95 | 19 | 22.18 | 56.05 | 56.67 | 30.65 | 37.57 | 34 | 43.55 | | | | | |
| | Vehicle load | 193 | 8 | 91 | 15 | 24 | 104 | 116 | 34 | 64 | 47 | 77 | | | | | |
| | Nodes | 35 | 227 | 228 | 409 | 299 | 294 | 230 | 295 | 274 | 436 | 424 | 300 | 293 | | | |
| **Route 25** | Arrival time | 30.56 | 52.25 | 25.7 | 24.59 | 54.03 | 55.76 | 28.35 | 59.26 | 28.48 | 28.48 | 31.36 | 26.2 | 33.08 | | | |
| | Vehicle load | 103 | 142 | 22 | 39 | 109 | 122 | 25 | 135 | 24 | 32 | 45 | 13 | 58 | | | |

Table 32. Routing detail of Instance 6’. Part 1.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 347 | 344 | 343 | 195 | 233 | 49 | | | | | | | | | |
| **Route 26** | Arrival time | 40.87 | 27.2 | 29.5 | 62.67 | 43.13 | 36.58 | | | | | | | | | |
| | Vehicle load | 42 | 21 | 35 | 58 | 56 | 47 | | | | | | | | | |
| | Nodes | 432 | 431 | 276 | 296 | 292 | 152 | 119 | 127 | 126 | 129 | 123 | 122 | 121 | 120 | 446 |
| **Route 27** | Arrival time | 57.44 | 64.96 | 49.29 | 38.06 | 27.12 | 62.19 | 57.62 | 35.58 | 37.4 | 37.4 | 37.6 | 38.53 | 39.23 | 41.01 | 41.99 |
| | Vehicle load | 164 | 113 | 110 | 71 | 12 | 135 | 71 | 36 | 47 | 60 | 73 | 86 | 94 | 104 | 116 |
| | Nodes | 435 | 434 | 297 | 275 | 298 | 447 | 166 | 168 | 192 | 167 | | | | | |
| **Route 28** | Arrival time | 54.11 | 28.26 | 42.09 | 44.01 | 55.88 | 29.22 | 30.12 | 46.62 | 48.64 | 49.12 | | | | | |
| | Vehicle load | 155 | 39 | 83 | 97 | 103 | 11 | 22 | 86 | 95 | 104 | | | | | |
| | Nodes | 172 | 175 | 176 | 178 | | | | | | | | | | | |
| **Route 29** | Arrival time | 55.91 | 38.9 | 38.9 | 33.22 | | | | | | | | | | | |
| | Vehicle load | 49 | 27 | 39 | 14 | | | | | | | | | | | |
| | Nodes | 272 | 79 | 277 | 73 | 82 | 83 | 291 | 74 | 273 | 433 | 80 | 278 | 235 | | |
| **Route 30** | Arrival time | 48.63 | 18.88 | 22.26 | 18.53 | 18.53 | 38.33 | 42 | 68.6 | 47.45 | 24.28 | 32.31 | 68.99 | 49.3 | | |
| | Vehicle load | 143 | 26 | 39 | 13 | 12 | 84 | 107 | 179 | 129 | 26 | 51 | 126 | 131 | | |
| | Nodes | 211 | 335 | 334 | 336 | | | | | | | | | | | |
| **Route 31** | Arrival time | 67.37 | 37.32 | 37.11 | 43.26 | | | | | | | | | | | |
| | Vehicle load | 135 | 10 | 40 | 51 | | | | | | | | | | | |
| | Nodes | 56 | 411 | 48 | 45 | 47 | 44 | 243 | 46 | 410 | | | | | | |
| **Route 32** | Arrival time | 61.63 | 61.52 | 46.24 | 49.67 | 51.44 | 35.83 | 59.73 | 27.27 | 42.35 | | | | | | |
| | Vehicle load | 84 | 79 | 38 | 52 | 66 | 38 | 34 | 13 | 51 | | | | | | |
| | Nodes | 346 | 225 | 345 | 12 | 50 | 52 | 219 | 238 | | | | | | | |
| **Route 33** | Arrival time | 55.1 | 18.4 | 50.9 | 39.71 | 57.85 | 66.91 | 49.45 | 30.83 | | | | | | | |
| | Vehicle load | 71 | 8 | 57 | 26 | 48 | 96 | 95 | 12 | | | | | | | |
| | Nodes | 196 | 226 | 223 | 215 | 248 | 247 | 241 | 361 | 222 | 218 | 220 | | | | |
| **Route 34** | Arrival time | 64.22 | 48.38 | 32.68 | 48.34 | 26.18 | 64.45 | 54.88 | 48.84 | 38.7 | 42.47 | 42.47 | | | | |
| | Vehicle load | 132 | 63 | 23 | 38 | 22 | 46 | 42 | 33 | 57 | 69 | 82 | | | | |
| | Nodes | 413 | 53 | 289 | 185 | 187 | 188 | 160 | 161 | | | | | | | |
| **Route 35** | Arrival time | 29.68 | 61.91 | 33.45 | 36.53 | 39.93 | 42.85 | 44.42 | 46.77 | | | | | | | |
| | Vehicle load | 16 | 82 | 36 | 50 | 60 | 73 | 85 | 97 | | | | | | | |
| | Nodes | 184 | 403 | 405 | 179 | 399 | 400 | 398 | 401 | 402 | 404 | | | | | |
| **Route 36** | Arrival time | 58.33 | 21.68 | 70.56 | 35.96 | 43.63 | 43.63 | 45.06 | 64.63 | 45.06 | 64.63 | | | | | |
| | Vehicle load | 87 | 12 | 177 | 24 | 36 | 49 | 63 | 152 | 76 | 164 | | | | | |
| | Nodes | 57 | 55 | 51 | 34 | 170 | 136 | 133 | 134 | 135 | | | | | | |
| **Route 37** | Arrival time | 72.54 | 48.2 | 53.25 | 42.38 | 62.35 | 49.72 | 51.84 | 51.84 | 51.84 | | | | | | |
| | Vehicle load | 73 | 24 | 35 | 36 | 144 | 77 | 89 | 99 | 112 | | | | | | |
| | Nodes | 54 | 342 | 340 | 341 | 339 | 338 | | | | | | | | | |
| **Route 38** | Arrival time | 53.93 | 44.22 | 37.09 | 32.27 | 52.7 | 52.7 | | | | | | | | | |
| | Vehicle load | 69 | 33 | 26 | 14 | 45 | 22 | | | | | | | | | |
| | Nodes | 30 | 147 | 124 | 125 | 130 | 111 | 112 | 392 | | | | | | | |
| **Route 39** | Arrival time | 20.08 | 44.1 | 26.78 | 58.12 | 44.99 | 27.78 | 35.55 | 56.62 | | | | | | | |
| | Vehicle load | 11 | 91 | 10 | 68 | 126 | 10 | 43 | 150 | | | | | | | |
| | Nodes | 39 | 116 | 115 | 118 | 100 | 107 | 106 | 103 | 101 | 102 | | | | | |
| **Route 40** | Arrival time | 17.53 | 54.43 | 50.58 | 51.88 | 23.77 | 47.72 | 59.3 | 64.65 | 30.3 | 61.8 | | | | | |
| | Vehicle load | 8 | 93 | 70 | 81 | 12 | 85 | 113 | 171 | 23 | 163 | | | | | |
| | Nodes | 229 | 438 | 231 | 224 | 364 | 284 | 285 | 282 | 143 | 169 | | | | | |
| **Route 41** | Arrival time | 20.21 | 72.64 | 58.73 | 19.28 | 52.44 | 57.92 | 57.92 | 59.04 | 40.03 | 41.63 | | | | | |
| | Vehicle load | 27 | 145 | 151 | 14 | 120 | 130 | 146 | 161 | 57 | 69 | | | | | |
| | Nodes | 197 | 201 | 200 | 204 | 202 | 199 | 205 | 203 | 198 | | | | | | |
| **Route 42** | Arrival time | 51.38 | 27.33 | 29.41 | 31.76 | 32.18 | 33.7 | 37.3 | 44.4 | 48.9 | | | | | | |
| | Vehicle load | 99 | 14 | 30 | 34 | 46 | 55 | 66 | 76 | 87 | | | | | | |
| | Nodes | 209 | 208 | 337 | | | | | | | | | | | | |
| **Route 43** | Arrival time | 61.5 | 74.9 | 54.28 | | | | | | | | | | | | |
| | Vehicle load | 112 | 76 | 62 | | | | | | | | | | | | |
| | Nodes | 368 | 369 | 164 | 440 | 162 | 131 | 132 | 283 | 142 | 140 | 141 | 70 | | | |
| **Route 44** | Arrival time | 44.13 | 69.56 | 45.66 | 49.37 | 71 | 37.55 | 75.13 | 62.94 | 32.28 | 49.47 | 50.7 | 43.54 | | | |
| | Vehicle load | 45 | 159 | 70 | 109 | 98 | 48 | 125 | 168 | 10 | 75 | 81 | 58 | | | |
| | Nodes | 236 | 237 | 442 | 216 | 217 | 239 | 290 | 240 | 214 | 212 | | | | | |
| **Route 45** | Arrival time | 22.2 | 44.88 | 46.76 | 61.37 | 61.37 | 50.86 | 72.63 | 59.53 | 40.26 | 58.36 | | | | | |
| | Vehicle load | 10 | 20 | 27 | 119 | 131 | 42 | 158 | 110 | 25 | 56 | | | | | |
| | Nodes | 395 | 110 | 113 | 163 | 117 | | | | | | | | | | |
| **Route 46** | Arrival time | 42.03 | 50.49 | 32.68 | 34.93 | 29.43 | | | | | | | | | | |
| | Vehicle load | 57 | 140 | 34 | 21 | 10 | | | | | | | | | | |
| | Nodes | 114 | 397 | 171 | 137 | | | | | | | | | | | |
| **Route 47** | Arrival time | 48.42 | 39.56 | 45.16 | 45.79 | | | | | | | | | | | |
| | Vehicle load | 41 | 29 | 49 | 59 | | | | | | | | | | | |
| | Nodes | 358 | 359 | 367 | 249 | 365 | 362 | 363 | 221 | 331 | 287 | | | | | |
| **Route 48** | Arrival time | 55.18 | 66.21 | 28.9 | 29.2 | 77.46 | 28.83 | 29.63 | 75.88 | 69.16 | 58.25 | | | | | |
| | Vehicle load | 75 | 78 | 35 | 45 | 168 | 15 | 24 | 192 | 178 | 134 | | | | | |
| | Nodes | 357 | 443 | 245 | 246 | 213 | 360 | 244 | 242 | 138 | 145 | 144 | | | | |
| **Route 49** | Arrival time | 57.45 | 59.88 | 60.38 | 53.61 | 61.53 | 63.13 | 25 | 60.88 | 55.93 | 45.62 | 44.15 | | | | |
| | Vehicle load | 104 | 87 | 54 | 49 | 67 | 69 | 15 | 64 | 93 | 70 | 77 | | | | |
| | Nodes | 441 | 366 | 281 | 193 | 165 | 288 | 194 | 177 | | | | | | | |
| **Route 50** | Arrival time | 41.11 | 64.19 | 51.53 | 32.37 | 38.48 | 33.17 | 36.19 | 57.35 | | | | | | | |
| | Vehicle load | 35 | 143 | 84 | 13 | 21 | 35 | 47 | 94 | | | | | | | |

Table 33. Routing detail of Instance 6’. Part 2.

| | | | | | |
|---|---|---|---|---|---|
| | Nodes | 393 | 286 | 186 | 191 |
| **Route 51** | Arrival time | 72.28 | 56.92 | 70.28 | 62.45 |
| | Vehicle load | 184 | 124 | 58 | 103 |
| | Nodes | 174 | 173 | | |
| **Route 52** | Arrival time | 34.84 | 24.18 | | |
| | Vehicle load | 11 | 10 | | |
| | Nodes | 174 | | | |
| **Route 53** | Arrival time | 34.84 | | | |
| | Vehicle load | 11 | | | |

Table 34. Routing detail of Instance 6’. Part 3.

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 33 | 190 | 189 | 131 | 132 | 283 | 142 | 140 | 141 | 168 | 192 | 167 | 144 | 70 | 145 | 136 | 133 | 134 | 135 |
| **Route 1** | Arrival time | 19.53 | 33.2 | 35.77 | 37.55 | 38 | 38.92 | 43.12 | 43.8 | 45.03 | 47.68 | 49.7 | 50.18 | 53.05 | 56.17 | 58.25 | 62.35 | 64.47 | 64.47 | 64.47 |
| | Vehicle load | 11 | 24 | 35 | 48 | 60 | 67 | 77 | 93 | 99 | 108 | 117 | 126 | 134 | 145 | 157 | 164 | 176 | 186 | 199 |
| | Nodes | 193 | 151 | 150 | 157 | 152 | 390 | 389 | 154 | 387 | 153 | 388 | 386 | 119 | 391 | 107 | 155 | 108 | 106 | |
| **Route 2** | Arrival time | 32.37 | 36.64 | 38.37 | 41.2 | 45.22 | 50.2 | 50.57 | 52.27 | 53.24 | 53.57 | 53.57 | 54.02 | 58.3 | 63.27 | 64.92 | 68.3 | 73.87 | 76.5 | |
| | Vehicle load | 13 | 25 | 37 | 48 | 56 | 66 | 75 | 86 | 98 | 106 | 116 | 129 | 143 | 155 | 166 | 176 | 185 | 194 | |
| | Nodes | 86 | 85 | 308 | 156 | 105 | 103 | 101 | 102 | 113 | 109 | 127 | 126 | 129 | 123 | 122 | 121 | 120 | | |
| **Route 3** | Arrival time | 17.43 | 18.41 | 22.61 | 43.71 | 51.49 | 57.01 | 60.44 | 60.44 | 62.82 | 67.47 | 72.32 | 74.14 | 74.14 | 74.34 | 75.27 | 75.97 | 77.75 | | |
| | Vehicle load | 9 | 20 | 32 | 43 | 57 | 65 | 76 | 89 | 100 | 112 | 126 | 137 | 150 | 163 | 176 | 184 | 194 | | |
| | Nodes | 201 | 200 | 334 | 335 | 336 | 337 | 338 | 342 | 208 | | | | | | | | | | |
| **Route 4** | Arrival time | 27.33 | 29.41 | 37.11 | 46.99 | 55.74 | 66.76 | 86.29 | 100.07 | 122.05 | | | | | | | | | | |
| | Vehicle load | 14 | 30 | 40 | 50 | 61 | 72 | 84 | 91 | 105 | | | | | | | | | | |
| | Nodes | 362 | 363 | 221 | 290 | 241 | 361 | 222 | 218 | 220 | 331 | 34 | 170 | 286 | 287 | 137 | 138 | 143 | | |
| **Route 5** | Arrival time | 28.83 | 29.63 | 34.45 | 38.53 | 40.91 | 42.44 | 48.99 | 52.76 | 52.76 | 59.24 | 67.86 | 70.96 | 73.98 | 75.31 | 79.68 | 82.81 | 88.91 | | |
| | Vehicle load | 15 | 24 | 38 | 52 | 65 | 73 | 85 | 97 | 110 | 120 | 135 | 145 | 157 | 167 | 177 | 189 | 198 | | |
| | Nodes | 380 | 379 | 87 | 382 | 383 | 381 | 88 | 385 | 384 | 307 | 93 | 310 | 309 | 450 | 396 | 111 | | | |
| **Route 6** | Arrival time | 12.75 | 14.4 | 18.13 | 19.33 | 22.28 | 24.2 | 26.67 | 32.02 | 35 | 38.68 | 44.53 | 50.06 | 51.83 | 71.56 | 73.23 | 81.38 | | | |
| | Vehicle load | 11 | 27 | 38 | 50 | 62 | 74 | 86 | 97 | 109 | 121 | 133 | 147 | 157 | 171 | 187 | 197 | | | |
| | Nodes | 292 | 230 | 423 | 305 | 303 | 302 | 301 | 304 | 299 | 294 | 274 | 436 | 424 | 300 | 447 | 166 | 165 | | |
| **Route 7** | Arrival time | 27.12 | 28.35 | 31.68 | 36.13 | 38.95 | 42.5 | 45.42 | 49.45 | 54.03 | 55.76 | 59.48 | 59.48 | 62.36 | 63.78 | 72.31 | 73.21 | 78.93 | | |
| | Vehicle load | 12 | 25 | 36 | 49 | 62 | 69 | 84 | 99 | 109 | 122 | 133 | 141 | 154 | 167 | 178 | 189 | 200 | | |
| | Nodes | 329 | 325 | 326 | 330 | 323 | 327 | 322 | 321 | 332 | 324 | 328 | 180 | 181 | 182 | 183 | 175 | | | |
| **Route 8** | Arrival time | 15.85 | 18.2 | 18.2 | 20.73 | 23.56 | 26.31 | 27.74 | 30.66 | 34.16 | 39.38 | 40.76 | 63.16 | 65.26 | 69.73 | 75.4 | 90.98 | | | |
| | Vehicle load | 12 | 26 | 38 | 53 | 61 | 75 | 89 | 102 | 113 | 125 | 137 | 147 | 161 | 174 | 187 | 200 | | | |
| | Nodes | 370 | 375 | 374 | 373 | 372 | 371 | 90 | 377 | 378 | 28 | 24 | 23 | 22 | 21 | 25 | 20 | 17 | | |
| **Route 9** | Arrival time | 12.7 | 15.28 | 19.4 | 20.18 | 24.51 | 27.99 | 34.12 | 34.89 | 40.32 | 50.24 | 65.77 | 68 | 71.52 | 75.6 | 77.23 | 78.81 | 81.68 | | |
| | Vehicle load | 8 | 19 | 29 | 41 | 53 | 63 | 78 | 90 | 101 | 113 | 124 | 135 | 149 | 162 | 174 | 187 | 199 | | |
| | Nodes | 264 | 260 | 445 | 444 | 250 | 251 | 257 | 128 | 158 | 159 | 149 | 148 | 146 | 147 | 124 | 446 | 130 | | |
| **Route 10** | Arrival time | 10.9 | 12.57 | 15.85 | 18.27 | 20.19 | 21.47 | 22.59 | 45.74 | 45.74 | 46.87 | 51.1 | 54.68 | 56.1 | 59.2 | 65.22 | 70.64 | 73.64 | | |
| | Vehicle load | 11 | 22 | 34 | 47 | 60 | 73 | 83 | 93 | 105 | 117 | 130 | 142 | 153 | 167 | 177 | 189 | 199 | | |
| | Nodes | 117 | 163 | 397 | 104 | 171 | 169 | 288 | 194 | 162 | 282 | 284 | 285 | 188 | 161 | 185 | 186 | | | |
| **Route 11** | Arrival time | 29.43 | 34.93 | 43.76 | 53.79 | 64.02 | 70.64 | 74.66 | 77.68 | 83.85 | 90.45 | 93.35 | 93.35 | 98.28 | 100.66 | 107.01 | 109.16 | | | |
| | Vehicle load | 10 | 21 | 34 | 44 | 57 | 69 | 82 | 94 | 108 | 123 | 133 | 149 | 162 | 174 | 188 | 200 | | | |
| | Nodes | 46 | 89 | 214 | 243 | 247 | 367 | 249 | 248 | 245 | 246 | 213 | 360 | 244 | 242 | 239 | 219 | | | |
| **Route 12** | Arrival time | 27.27 | 44.25 | 62.92 | 68.29 | 73.01 | 75.36 | 75.66 | 77.26 | 80.28 | 81.21 | 83.29 | 84.54 | 85.77 | 87.24 | 93.46 | 96.33 | | | |
| | Vehicle load | 13 | 25 | 38 | 47 | 59 | 72 | 82 | 94 | 106 | 117 | 128 | 143 | 158 | 172 | 181 | 194 | | | |
| | Nodes | 420 | 353 | 58 | 59 | 139 | 60 | 354 | 36 | 31 | 32 | 62 | 61 | 71 | 72 | 65 | 67 | 69 | 442 | |
| **Route 13** | Arrival time | 12.88 | 15.28 | 18.98 | 18.98 | 18.98 | 19.51 | 20.98 | 23.06 | 26.61 | 26.94 | 28.87 | 32.49 | 36.12 | 36.12 | 44.57 | 46.45 | 47.05 | 64.07 | |
| | Vehicle load | 10 | 21 | 34 | 42 | 58 | 68 | 81 | 90 | 102 | 114 | 124 | 135 | 148 | 160 | 171 | 182 | 192 | 199 | |
| | Nodes | 313 | 315 | 317 | 311 | 316 | 91 | 92 | 14 | 16 | 26 | 27 | 15 | 19 | 18 | 393 | | | | |
| **Route 14** | Arrival time | 9.03 | 13.5 | 17.22 | 20.39 | 23.09 | 26.92 | 34.05 | 42.97 | 49.22 | 55.3 | 61.8 | 68.68 | 75.06 | 82.24 | 106.74 | | | | |
| | Vehicle load | 14 | 27 | 41 | 54 | 66 | 78 | 90 | 105 | 116 | 125 | 133 | 144 | 160 | 173 | 186 | | | | |
| | Nodes | 100 | 112 | 392 | 110 | 395 | 115 | 118 | 116 | 357 | 223 | 215 | 365 | 237 | 240 | 289 | 366 | 426 | | |
| **Route 15** | Arrival time | 23.77 | 32.65 | 36.33 | 45.6 | 51.88 | 60.43 | 61.73 | 64.28 | 67.3 | 71.35 | 76.88 | 80.36 | 82.28 | 88.01 | 97.21 | 106.66 | 113.46 | | |
| | Vehicle load | 12 | 21 | 31 | 45 | 59 | 72 | 83 | 95 | 106 | 114 | 125 | 135 | 145 | 160 | 172 | 184 | 194 | | |
| | Nodes | 224 | 229 | 63 | 429 | 234 | 428 | 425 | 427 | 68 | 439 | 430 | 421 | 412 | 422 | 295 | | | | |
| **Route 16** | Arrival time | 19.28 | 20.21 | 25.48 | 26.78 | 28.26 | 31.31 | 33.31 | 34.96 | 36.73 | 39.28 | 40.25 | 46.87 | 50.32 | 53.29 | 56.14 | | | | |
| | Vehicle load | 14 | 27 | 39 | 54 | 68 | 79 | 91 | 103 | 116 | 126 | 138 | 153 | 168 | 182 | 195 | | | | |
| | Nodes | 341 | 340 | 339 | 233 | 195 | 54 | 49 | 344 | 343 | 47 | 57 | | | | | | | | |
| **Route 17** | Arrival time | 32.27 | 37.09 | 47.44 | 59.74 | 65.56 | 70.48 | 78.18 | 88.01 | 90.31 | 102.61 | 115.36 | | | | | | | | |
| | Vehicle load | 14 | 26 | 38 | 47 | 60 | 73 | 85 | 98 | 112 | 126 | 141 | | | | | | | | |
| | Nodes | 42 | 43 | 37 | 38 | 41 | 39 | 415 | 417 | 416 | 414 | 413 | 12 | 48 | 45 | 44 | 410 | | | |
| **Route 18** | Arrival time | 19 | 22.18 | 23.06 | 23.68 | 29.78 | 32.01 | 36.86 | 40.84 | 42.92 | 46.27 | 52.32 | 62.35 | 68.88 | 72.31 | 76.58 | 83.1 | | | |
| | Vehicle load | 15 | 24 | 37 | 49 | 63 | 71 | 84 | 101 | 111 | 124 | 132 | 142 | 154 | 168 | 184 | 197 | | | |
| | Nodes | 73 | 79 | 277 | 81 | 276 | 296 | 297 | 275 | 298 | 293 | 160 | 440 | 364 | 187 | 238 | 191 | | | |
| **Route 19** | Arrival time | 18.53 | 18.88 | 22.26 | 24.41 | 29.34 | 33.27 | 37.3 | 39.22 | 45.75 | 48.72 | 59.17 | 62.17 | 65.24 | 68.32 | 78.52 | 89.79 | | | |
| | Vehicle load | 13 | 26 | 39 | 48 | 61 | 74 | 86 | 100 | 112 | 125 | 137 | 149 | 160 | 170 | 182 | 192 | | | |
| | Nodes | 178 | 176 | 174 | 173 | 399 | 400 | 398 | 401 | 402 | 404 | 179 | | | | | | | | |
| **Route 20** | Arrival time | 33.22 | 38.9 | 54.92 | 62.85 | 85.2 | 85.2 | 86.63 | 86.63 | 86.63 | 86.63 | 99.08 | | | | | | | | |
| | Vehicle load | 14 | 26 | 37 | 47 | 59 | 72 | 86 | 101 | 114 | 126 | 138 | | | | | | | | |
| | Nodes | 82 | 448 | 66 | 83 | 84 | 291 | 74 | 75 | 76 | 77 | 78 | 30 | 29 | 409 | 281 | 177 | 164 | | |
| **Route 21** | Arrival time | 18.53 | 22.9 | 23.4 | 25.7 | 26.67 | 29.37 | 34.3 | 35.13 | 36.91 | 38.96 | 42.38 | 48.38 | 51.86 | 57.51 | 67.19 | 73.01 | 80.24 | | |
| | Vehicle load | 12 | 21 | 32 | 43 | 53 | 66 | 77 | 92 | 102 | 113 | 126 | 137 | 147 | 159 | 173 | 183 | 193 | | |
| | Nodes | 207 | 206 | 204 | 202 | 199 | 205 | 203 | 198 | 197 | 209 | 210 | 211 | 8 | 9 | 7 | 10 | | | |
| **Route 22** | Arrival time | 26.88 | 28.68 | 31.76 | 32.18 | 33.7 | 37.3 | 44.4 | 48.9 | 51.38 | 61.5 | 66.77 | 72.07 | 82.7 | 84.38 | 85.95 | 85.95 | | | |
| | Vehicle load | 14 | 25 | 34 | 46 | 55 | 66 | 76 | 87 | 99 | 112 | 127 | 141 | 153 | 168 | 182 | 198 | | | |
| | Nodes | 225 | 346 | 55 | 53 | 52 | 51 | 50 | 411 | 226 | 359 | 216 | 217 | 441 | 236 | 443 | 358 | | | |
| **Route 23** | Arrival time | 18.4 | 21.3 | 29.05 | 32.88 | 37.88 | 40.06 | 44.66 | 47.78 | 54.93 | 62.01 | 65.03 | 65.03 | 68.2 | 70.73 | 75.85 | 79.4 | | | |
| | Vehicle load | 8 | 22 | 34 | 47 | 61 | 72 | 85 | 98 | 110 | 124 | 139 | 151 | 163 | 173 | 185 | 197 | | | |
| | Nodes | 433 | 80 | 431 | 125 | 369 | 368 | 212 | 438 | 228 | 231 | 232 | 227 | 196 | 35 | 40 | | | | |
| **Route 24** | Arrival time | 19.2 | 19.42 | 23.44 | 34.21 | 55.24 | 58.11 | 67.99 | 77.21 | 79.36 | 83.21 | 90.16 | 92.48 | 98.71 | 104.91 | 117.99 | | | | |
| | Vehicle load | 14 | 26 | 36 | 49 | 65 | 75 | 89 | 102 | 113 | 122 | 136 | 147 | 163 | 176 | 190 | | | | |
| | Nodes | 403 | 405 | 184 | 172 | 345 | 56 | 347 | 418 | 278 | | | | | | | | | | |
| **Route 25** | Arrival time | 21.68 | 21.68 | 34.68 | 47.95 | 70.45 | 75.92 | 88.39 | 101.41 | 112.28 | | | | | | | | | | |
| | Vehicle load | 12 | 25 | 36 | 45 | 60 | 73 | 84 | 95 | 108 | | | | | | | | | | |

Table 35. Routing detail of Instance 7. Part 1.

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 312 | 314 | 449 | 64 | 394 | 114 | 267 | 96 | | | | | | | | | |
| **Route 26** | Arrival time | 7.23 | 10.43 | 16.58 | 48.43 | 74.51 | 91.01 | 110.49 | 120.71 | | | | | | | | | |
| | Vehicle load | 14 | 26 | 38 | 56 | 64 | 75 | 86 | 100 | | | | | | | | | |
| | Nodes | 11 | 13 | 5 | 2 | 3 | 4 | 263 | 262 | 261 | 356 | 259 | 252 | 255 | 254 | 256 | 6 | 253 |
| **Route 27** | Arrival time | 7.33 | 9.21 | 15.93 | 17.9 | 18.55 | 21.42 | 25.49 | 29.24 | 30.22 | 33.95 | 37.02 | 39.82 | 45.09 | 47.01 | 49.69 | 55.11 | 60.59 |
| | Vehicle load | 9 | 21 | 31 | 44 | 54 | 63 | 76 | 87 | 99 | 109 | 123 | 136 | 149 | 162 | 174 | 187 | 200 |
| | Nodes | 271 | 270 | 269 | 435 | 434 | 432 | 272 | 273 | 235 | 355 | 351 | 352 | 437 | 419 | 258 | 349 | |
| **Route 28** | Arrival time | 12.43 | 19.01 | 21.73 | 25.66 | 29.04 | 32.87 | 35.67 | 36.85 | 42.43 | 53.18 | 57.86 | 60.49 | 63.77 | 67.49 | 77.44 | 82.44 | |
| | Vehicle load | 14 | 26 | 38 | 50 | 63 | 72 | 86 | 102 | 113 | 124 | 134 | 146 | 156 | 171 | 185 | 198 | |
| | Nodes | 320 | 319 | 318 | 280 | 279 | 306 | 333 | 406 | 407 | 408 | 350 | 95 | 376 | 265 | 268 | | |
| **Route 29** | Arrival time | 9.65 | 19.68 | 27.6 | 28.95 | 32.85 | 35.83 | 47.76 | 58.28 | 60.83 | 66.45 | 72.15 | 83.6 | 85.27 | 89.49 | 99.46 | | |
| | Vehicle load | 11 | 24 | 35 | 50 | 65 | 75 | 90 | 102 | 119 | 132 | 144 | 156 | 167 | 179 | 193 | | |
| | Nodes | 94 | 99 | 97 | 98 | 266 | 348 | 1 | | | | | | | | | | |
| **Route 30** | Arrival time | 9.33 | 16.08 | 20 | 20 | 37.15 | 49.42 | 56.49 | | | | | | | | | | |
| | Vehicle load | 14 | 26 | 40 | 55 | 64 | 75 | 84 | | | | | | | | | | |

Table 36. Routing detail of Instance 7. Part 2.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 33 | 190 | 189 | 131 | 143 | 169 | 144 | 168 | 192 | 167 | 288 | 132 | 285 | 188 | 365 |
| **Route 1** | Arrival time | 19.53 | 33.2 | 35.77 | 37.55 | 40.03 | 41.63 | 44.15 | 46.62 | 48.64 | 49.12 | 52.35 | 60 | 63.15 | 68.08 | 73.88 |
| | Vehicle load | 11 | 24 | 35 | 48 | 57 | 69 | 77 | 86 | 95 | 104 | 117 | 129 | 145 | 158 | 168 |
| | Nodes | 193 | 151 | 150 | 157 | 152 | 389 | 154 | 387 | 153 | 388 | 386 | 391 | 107 | 108 | |
| **Route 2** | Arrival time | 32.37 | 36.64 | 38.37 | 41.2 | 45.22 | 49.84 | 51.54 | 52.51 | 52.84 | 52.84 | 53.29 | 59.01 | 60.66 | 63.74 | |
| | Vehicle load | 13 | 25 | 37 | 48 | 56 | 65 | 76 | 88 | 96 | 106 | 119 | 131 | 142 | 151 | |
| | Nodes | 86 | 156 | 105 | 155 | 163 | 221 | | | | | | | | | |
| **Route 3** | Arrival time | 17.43 | 40.65 | 48.43 | 52.56 | 58.09 | 69.32 | | | | | | | | | |
| | Vehicle load | 9 | 20 | 34 | 44 | 55 | 69 | | | | | | | | | |
| | Nodes | 201 | 200 | 334 | 336 | 337 | 208 | | | | | | | | | |
| **Route 4** | Arrival time | 27.33 | 29.41 | 37.11 | 43.26 | 54.28 | 74.9 | | | | | | | | | |
| | Vehicle load | 14 | 30 | 40 | 51 | 62 | 76 | | | | | | | | | |
| | Nodes | 362 | 363 | 289 | 187 | 185 | 186 | 136 | 134 | 135 | 282 | 283 | 331 | | | |
| **Route 5** | Arrival time | 28.83 | 29.63 | 33.45 | 37.2 | 39.32 | 41.47 | 48.97 | 51.09 | 51.09 | 54.17 | 58.07 | 64.29 | | | |
| | Vehicle load | 15 | 24 | 36 | 46 | 60 | 72 | 79 | 89 | 102 | 117 | 124 | 134 | | | |
| | Nodes | 380 | 85 | 308 | 385 | 384 | 307 | 93 | 377 | 90 | 378 | 379 | 87 | 267 | 96 | |
| **Route 6** | Arrival time | 12.75 | 22.28 | 26.48 | 29.66 | 32.64 | 36.32 | 42.17 | 47.92 | 48.24 | 53.37 | 57.25 | 60.98 | 69.68 | 79.9 | |
| | Vehicle load | 11 | 22 | 34 | 45 | 57 | 69 | 81 | 93 | 108 | 119 | 135 | 146 | 157 | 171 | |
| | Nodes | 111 | 109 | 390 | 119 | 127 | 126 | 123 | 122 | 121 | 446 | 110 | | | | |
| **Route 7** | Arrival time | 27.78 | 30.73 | 38.81 | 42.23 | 46.95 | 48.77 | 48.97 | 49.9 | 50.6 | 53.35 | 60.43 | | | | |
| | Vehicle load | 10 | 22 | 32 | 46 | 60 | 71 | 84 | 97 | 105 | 117 | 131 | | | | |
| | Nodes | 292 | 230 | 423 | 305 | 303 | 302 | 301 | 304 | 299 | 293 | 159 | | | | |
| **Route 8** | Arrival time | 27.12 | 28.35 | 31.68 | 36.13 | 38.95 | 42.5 | 45.42 | 49.45 | 54.03 | 58.08 | 69.96 | | | | |
| | Vehicle load | 12 | 25 | 36 | 49 | 62 | 69 | 84 | 99 | 109 | 122 | 134 | | | | |
| | Nodes | 447 | 166 | 145 | 70 | 138 | 140 | 141 | 133 | 286 | 287 | 170 | 290 | | | |
| **Route 9** | Arrival time | 29.22 | 30.12 | 37.59 | 37.76 | 39.74 | 40.71 | 41.94 | 47.17 | 52.25 | 53.58 | 57.68 | 67.96 | | | |
| | Vehicle load | 11 | 22 | 34 | 45 | 57 | 73 | 79 | 91 | 103 | 113 | 123 | 137 | | | |
| | Nodes | 329 | 172 | 182 | 180 | 181 | 183 | 176 | | | | | | | | |
| **Route 10** | Arrival time | 15.85 | 25.35 | 38.65 | 42.42 | 44.52 | 49.97 | 65.55 | | | | | | | | |
| | Vehicle load | 12 | 21 | 34 | 44 | 58 | 71 | 83 | | | | | | | | |
| | Nodes | 370 | 371 | 375 | 374 | 372 | 373 | 97 | 98 | 99 | 81 | 426 | 448 | | | |
| **Route 11** | Arrival time | 12.7 | 17.68 | 22.55 | 26.67 | 30.79 | 34.31 | 40.29 | 40.29 | 42.14 | 55.21 | 62.79 | 68.26 | | | |
| | Vehicle load | 8 | 18 | 29 | 39 | 51 | 63 | 77 | 92 | 104 | 113 | 123 | 132 | | | |
| | Nodes | 264 | 254 | 256 | 6 | 255 | 444 | 250 | 251 | 257 | 31 | 32 | 62 | 61 | 72 | |
| **Route 12** | Arrival time | 10.9 | 18.53 | 21.21 | 26.63 | 30.18 | 38.18 | 40.1 | 41.38 | 42.5 | 53.37 | 53.7 | 55.63 | 59.25 | 62.88 | |
| | Vehicle load | 11 | 24 | 36 | 49 | 62 | 75 | 88 | 101 | 111 | 123 | 135 | 145 | 156 | 168 | |
| | Nodes | 117 | 397 | 104 | 393 | 26 | | | | | | | | | | |
| **Route 13** | Arrival time | 29.43 | 38.4 | 48.43 | 56.1 | 79.88 | | | | | | | | | | |
| | Vehicle load | 10 | 23 | 33 | 46 | 55 | | | | | | | | | | |
| | Nodes | 46 | 89 | 247 | | | | | | | | | | | | |
| **Route 14** | Arrival time | 27.27 | 44.25 | 64.2 | | | | | | | | | | | | |
| | Vehicle load | 13 | 25 | 37 | | | | | | | | | | | | |
| | Nodes | 300 | 274 | 436 | 424 | 294 | 296 | 297 | 275 | 276 | 439 | 430 | 428 | 421 | 438 | |
| **Route 15** | Arrival time | 26.2 | 28.48 | 28.48 | 31.36 | 33.69 | 36.89 | 40.92 | 42.84 | 48.12 | 51.82 | 52.79 | 56.02 | 59.67 | 67.24 | |
| | Vehicle load | 13 | 24 | 32 | 45 | 58 | 71 | 83 | 97 | 110 | 120 | 132 | 143 | 158 | 171 | |
| | Nodes | 420 | 355 | 58 | 139 | 354 | 60 | 36 | 35 | 59 | 351 | 352 | 353 | 437 | 419 | 369 |
| **Route 16** | Arrival time | 12.88 | 18.03 | 24.36 | 24.36 | 25.31 | 26.79 | 28.87 | 31.62 | 35.75 | 39.38 | 42.01 | 43.21 | 46.64 | 50.36 | 64.36 |
| | Vehicle load | 10 | 21 | 34 | 50 | 63 | 73 | 82 | 95 | 103 | 113 | 125 | 136 | 146 | 161 | 177 |
| | Nodes | 313 | 312 | 311 | 317 | 316 | 315 | 91 | 92 | 14 | 17 | | | | | |
| **Route 17** | Arrival time | 9.42 | 12.75 | 21.07 | 23.55 | 26.57 | 29.77 | 34.95 | 42.08 | 51 | 62.1 | | | | | |
| | Vehicle load | 14 | 28 | 41 | 55 | 67 | 80 | 92 | 104 | 119 | 131 | | | | | |
| | Nodes | 142 | 137 | 34 | 171 | 284 | 161 | 162 | | | | | | | | |
| **Route 18** | Arrival time | 32.28 | 35.75 | 42.6 | 45.38 | 53.15 | 56.88 | 61.91 | | | | | | | | |
| | Vehicle load | 10 | 20 | 35 | 48 | 58 | 70 | 84 | | | | | | | | |
| | Nodes | 100 | 106 | 103 | 101 | 102 | 113 | 392 | 395 | 40 | | | | | | |
| **Route 19** | Arrival time | 23.77 | 33.64 | 39.24 | 42.67 | 42.67 | 45.05 | 51.62 | 57.37 | 82.37 | | | | | | |
| | Vehicle load | 12 | 21 | 29 | 40 | 53 | 64 | 74 | 88 | 102 | | | | | | |
| | Nodes | 224 | 409 | 422 | 295 | 149 | 148 | 146 | 128 | 158 | 177 | 366 | | | | |
| **Route 20** | Arrival time | 19.28 | 24.1 | 27.07 | 29.92 | 37.9 | 41.48 | 42.9 | 49.97 | 49.97 | 56.87 | 67.14 | | | | |
| | Vehicle load | 14 | 26 | 40 | 53 | 66 | 78 | 89 | 99 | 111 | 121 | 133 | | | | |
| | Nodes | 341 | 340 | 342 | 195 | 52 | 57 | | | | | | | | | |
| **Route 21** | Arrival time | 32.27 | 37.09 | 44.22 | 51.24 | 61.76 | 66.08 | | | | | | | | | |
| | Vehicle load | 14 | 26 | 33 | 46 | 60 | 75 | | | | | | | | | |
| | Nodes | 42 | 43 | 416 | 414 | 415 | 41 | 417 | 196 | 37 | 38 | | | | | |
| **Route 22** | Arrival time | 19 | 22.18 | 30.65 | 34 | 37.93 | 44.33 | 54.25 | 59.9 | 65.18 | 65.8 | | | | | |
| | Vehicle load | 15 | 24 | 34 | 47 | 60 | 74 | 91 | 107 | 120 | 132 | | | | | |
| | Nodes | 165 | 194 | 160 | 440 | 364 | 222 | 218 | | | | | | | | |
| **Route 23** | Arrival time | 31.1 | 34.08 | 42.38 | 45.38 | 48.45 | 58.17 | 61.94 | | | | | | | | |
| | Vehicle load | 11 | 23 | 35 | 47 | 58 | 70 | 82 | | | | | | | | |
| | Nodes | 73 | 79 | 277 | 68 | 425 | 427 | 412 | 63 | 429 | 65 | 69 | 66 | 234 | 431 | 278 |
| **Route 24** | Arrival time | 18.53 | 18.88 | 22.26 | 31.13 | 34.85 | 36.5 | 41.05 | 45.88 | 47.18 | 49.68 | 51.06 | 51.16 | 55.21 | 61.01 | 65.04 |
| | Vehicle load | 13 | 26 | 39 | 52 | 64 | 76 | 91 | 103 | 118 | 129 | 139 | 150 | 164 | 174 | 187 |
| | Nodes | 178 | 175 | 174 | | | | | | | | | | | | |
| **Route 25** | Arrival time | 33.22 | 38.9 | 54.92 | | | | | | | | | | | | |
| | Vehicle load | 14 | 27 | 38 | | | | | | | | | | | | |

Table 37. Routing detail of Instance 8. Part 1.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 82 | 67 | 147 | 120 | 129 | 125 | 1 | | | | | |
| **Route 26** | Arrival time | 18.53 | 23.33 | 32.45 | 41.13 | 43.95 | 49.05 | 75.28 | | | | | |
| | Vehicle load | 12 | 23 | 37 | 47 | 60 | 73 | 82 | | | | | |
| | Nodes | 207 | 206 | 204 | 202 | 199 | 205 | 203 | 198 | 209 | | | |
| **Route 27** | Arrival time | 26.88 | 28.68 | 31.76 | 32.18 | 33.7 | 37.3 | 44.4 | 48.9 | 58.6 | | | |
| | Vehicle load | 14 | 25 | 34 | 46 | 55 | 66 | 76 | 87 | 100 | | | |
| | Nodes | 225 | 413 | 12 | 48 | 45 | 47 | 367 | 217 | | | | |
| **Route 28** | Arrival time | 18.4 | 24.48 | 34.51 | 41.04 | 44.47 | 46.24 | 59.71 | 62.81 | | | | |
| | Vehicle load | 8 | 16 | 26 | 38 | 52 | 66 | 79 | 91 | | | | |
| | Nodes | 433 | 298 | 281 | 191 | 84 | 235 | | | | | | |
| **Route 29** | Arrival time | 19.2 | 28.87 | 42.35 | 49.45 | 59.58 | 62.6 | | | | | | |
| | Vehicle load | 14 | 26 | 40 | 50 | 60 | 71 | | | | | | |
| | Nodes | 236 | 237 | 248 | 249 | 239 | 220 | 219 | 240 | | | | |
| **Route 30** | Arrival time | 22.2 | 25.75 | 29.23 | 30.83 | 35.8 | 39.98 | 46.96 | 57.04 | | | | |
| | Vehicle load | 10 | 20 | 32 | 42 | 51 | 64 | 77 | 92 | | | | |
| | Nodes | 403 | 179 | 399 | 400 | 398 | 401 | 402 | 404 | 405 | | | |
| **Route 31** | Arrival time | 21.68 | 35.96 | 43.63 | 43.63 | 45.06 | 45.06 | 45.06 | 45.06 | 50.99 | | | |
| | Vehicle load | 12 | 24 | 36 | 49 | 63 | 78 | 91 | 103 | 116 | | | |
| | Nodes | 335 | 338 | | | | | | | | | | |
| **Route 32** | Arrival time | 37.32 | 52.7 | | | | | | | | | | |
| | Vehicle load | 10 | 22 | | | | | | | | | | |
| | Nodes | 449 | 450 | 396 | 112 | | | | | | | | |
| **Route 33** | Arrival time | 12.26 | 37.83 | 39.5 | 46.58 | | | | | | | | |
| | Vehicle load | 12 | 26 | 42 | 51 | | | | | | | | |
| | Nodes | 11 | 325 | 323 | 326 | 330 | 327 | 322 | 321 | 332 | 324 | 328 | |
| **Route 34** | Arrival time | 12.42 | 24.42 | 28.6 | 32.5 | 35.03 | 37.98 | 39.41 | 42.33 | 45.83 | 51.05 | 52.43 | |
| | Vehicle load | 9 | 23 | 31 | 43 | 58 | 72 | 86 | 99 | 110 | 122 | 134 | |
| | Nodes | 262 | 356 | 260 | 258 | 445 | 418 | 75 | 76 | 77 | 78 | 83 | 227 |
| **Route 35** | Arrival time | 12.45 | 15.77 | 19.49 | 25.21 | 28.93 | 36.88 | 42.53 | 44.31 | 46.36 | 49.78 | 55.11 | 61.76 |
| | Vehicle load | 11 | 21 | 32 | 46 | 58 | 69 | 84 | 94 | 105 | 118 | 129 | 140 |
| | Nodes | 24 | 23 | 22 | 21 | 25 | 20 | 15 | 16 | 27 | 309 | | |
| **Route 36** | Arrival time | 20.92 | 23.15 | 26.67 | 30.75 | 32.38 | 33.96 | 40.39 | 43.31 | 51.38 | 59.9 | | |
| | Vehicle load | 11 | 22 | 36 | 49 | 61 | 74 | 85 | 96 | 104 | 114 | | |
| | Nodes | 71 | 291 | 30 | 29 | 229 | 231 | 228 | 232 | 74 | | | |
| **Route 37** | Arrival time | 20.35 | 25.12 | 31.57 | 35.05 | 37.63 | 41.26 | 46.89 | 52.21 | 60.88 | | | |
| | Vehicle load | 13 | 26 | 37 | 47 | 60 | 69 | 80 | 94 | 105 | | | |
| | Nodes | 271 | 434 | 272 | 164 | 441 | 216 | 245 | 360 | | | | |
| **Route 38** | Arrival time | 12.88 | 20.26 | 24.86 | 40.68 | 46.58 | 52.21 | 57.18 | 59.93 | | | | |
| | Vehicle load | 14 | 27 | 41 | 51 | 63 | 78 | 90 | 105 | | | | |
| | Nodes | 39 | 344 | 343 | 49 | 233 | | | | | | | |
| **Route 39** | Arrival time | 17.53 | 33.31 | 35.61 | 42.69 | 49.24 | | | | | | | |
| | Vehicle load | 8 | 21 | 35 | 47 | 56 | | | | | | | |
| | Nodes | 238 | 214 | 243 | 242 | 212 | 213 | 359 | | | | | |
| **Route 40** | Arrival time | 30.83 | 40.26 | 45.63 | 50.08 | 53.58 | 56.75 | 61.18 | | | | | |
| | Vehicle load | 12 | 25 | 34 | 48 | 62 | 73 | 87 | | | | | |
| | Nodes | 124 | 130 | 115 | 118 | 116 | 357 | 358 | | | | | |
| **Route 41** | Arrival time | 26.78 | 33.08 | 46.25 | 47.55 | 50.1 | 53.12 | 54.8 | | | | | |
| | Vehicle load | 10 | 20 | 33 | 44 | 56 | 67 | 79 | | | | | |
| | Nodes | 320 | 319 | 184 | 7 | | | | | | | | |
| **Route 42** | Arrival time | 14.66 | 24.69 | 41.24 | 62.36 | | | | | | | | |
| | Vehicle load | 11 | 24 | 35 | 49 | | | | | | | | |
| | Nodes | 318 | 314 | 18 | 19 | 349 | 350 | | | | | | |
| **Route 43** | Arrival time | 15.17 | 25.64 | 38.69 | 45.69 | 64.84 | 64.84 | | | | | | |
| | Vehicle load | 11 | 23 | 36 | 52 | 65 | 77 | | | | | | |
| | Nodes | 244 | 361 | 241 | 215 | 442 | 223 | 246 | | | | | |
| **Route 44** | Arrival time | 25 | 28.6 | 30.13 | 36.5 | 38.93 | 44.3 | 49.13 | | | | | |
| | Vehicle load | 15 | 23 | 36 | 47 | 54 | 62 | 73 | | | | | |
| | Nodes | 310 | 28 | 382 | 383 | 381 | 88 | 269 | 435 | 432 | | | |
| **Route 45** | Arrival time | 17.17 | 25.59 | 36.59 | 39.54 | 41.46 | 43.93 | 53.86 | 57.79 | 61.12 | | | |
| | Vehicle load | 14 | 26 | 38 | 50 | 62 | 74 | 86 | 98 | 107 | | | |
| | Nodes | 64 | | | | | | | | | | | |
| **Route 46** | Arrival time | 33.07 | | | | | | | | | | | |
| | Vehicle load | 18 | | | | | | | | | | | |
| | Nodes | 4 | 261 | 263 | 2 | 5 | 3 | 253 | 9 | 8 | 13 | | |
| **Route 47** | Arrival time | 17.62 | 26.15 | 30.87 | 36.25 | 38.22 | 40.55 | 48.63 | 55.31 | 56.99 | 64.06 | | |
| | Vehicle load | 9 | 21 | 34 | 47 | 57 | 67 | 80 | 95 | 107 | 119 | | |
| | Nodes | 55 | 51 | 50 | 411 | 410 | 44 | 53 | | | | | |
| **Route 48** | Arrival time | 20.68 | 25.73 | 30.33 | 33.45 | 34.57 | 43.35 | 54.68 | | | | | |
| | Vehicle load | 12 | 23 | 36 | 49 | 62 | 78 | 91 | | | | | |
| | Nodes | 394 | 114 | 268 | 376 | | | | | | | | |
| **Route 49** | Arrival time | 20.27 | 36.77 | 52.5 | 60.08 | | | | | | | | |
| | Vehicle load | 8 | 19 | 33 | 44 | | | | | | | | |
| | Nodes | 339 | 54 | 56 | 345 | | | | | | | | |
| **Route 50** | Arrival time | 29.07 | 43.85 | 50.75 | 58.38 | | | | | | | | |
| | Vehicle load | 12 | 25 | 38 | 53 | | | | | | | | |

Table 38. Routing detail of Instance 8. Part 2.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Nodes | 10 | 210 | 211 | 347 | | |
| **Route 51** | Arrival time | 19.63 | 32.35 | 37.65 | 51.63 | | |
| | Vehicle load | 16 | 31 | 45 | 56 | | |
| | Nodes | 226 | 443 | 368 | 80 | 273 | |
| **Route 52** | Arrival time | 20.27 | 30.79 | 35.69 | 52.24 | 55.66 | |
| | Vehicle load | 12 | 24 | 34 | 46 | 62 | |
| | Nodes | 197 | 346 | 266 | | | |
| **Route 53** | Arrival time | 20.72 | 33.79 | 50.94 | | | |
| | Vehicle load | 12 | 26 | 35 | | | |
| | Nodes | 280 | 333 | 406 | 407 | 259 | 252 |
| **Route 54** | Arrival time | 20.49 | 34.27 | 44.79 | 47.34 | 56.36 | 59.16 |
| | Vehicle load | 15 | 30 | 42 | 59 | 73 | 86 |
| | Nodes | 94 | 270 | 265 | 95 | 408 | |
| **Route 55** | Arrival time | 21.01 | 31.23 | 44.26 | 46.06 | 54.98 | |
| | Vehicle load | 14 | 26 | 38 | 50 | 63 | |
| | Nodes | 348 | 306 | 279 | | | |
| **Route 56** | Arrival time | 27.27 | 39.64 | 42.59 | | | |
| | Vehicle load | 11 | 21 | 36 | | | |
| | Nodes | 173 | | | | | |
| **Route 57** | Arrival time | 29.18 | | | | | |
| | Vehicle load | 10 | | | | | |

Table 39. Routing detail of Instance 8. Part 3.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 33 | 190 | 189 | 131 | 143 | 169 | 144 | 168 | 192 | 167 | 151 | 157 | 152 | 154 | 387 | 159 |
| **Route 1** | Arrival time | 19.53 | 33.2 | 35.77 | 37.55 | 40.03 | 41.63 | 44.15 | 46.62 | 48.64 | 49.12 | 54.49 | 58.17 | 62.19 | 66.44 | 67.41 | 73.78 |
| | Vehicle load | 11 | 24 | 35 | 48 | 57 | 69 | 77 | 86 | 95 | 104 | 116 | 127 | 135 | 146 | 158 | 170 |
| | Nodes | 193 | 150 | 153 | 388 | 390 | 389 | 391 | 107 | 155 | 108 | 106 | 132 | | | | |
| **Route 2** | Arrival time | 32.37 | 36.3 | 39.73 | 39.73 | 43.08 | 43.45 | 46.07 | 47.72 | 51.1 | 56.67 | 59.3 | 75.13 | | | | |
| | Vehicle load | 13 | 25 | 33 | 43 | 53 | 62 | 74 | 85 | 95 | 104 | 113 | 125 | | | | |
| | Nodes | 86 | 85 | 308 | 156 | 105 | 119 | 386 | 162 | | | | | | | | |
| **Route 3** | Arrival time | 17.43 | 18.41 | 22.61 | 43.71 | 51.49 | 57.62 | 60.77 | 71 | | | | | | | | |
| | Vehicle load | 9 | 20 | 32 | 43 | 57 | 71 | 84 | 98 | | | | | | | | |
| | Nodes | 201 | 200 | 334 | 336 | 337 | 208 | | | | | | | | | | |
| **Route 4** | Arrival time | 27.33 | 29.41 | 37.11 | 43.26 | 54.28 | 74.9 | | | | | | | | | | |
| | Vehicle load | 14 | 30 | 40 | 51 | 62 | 76 | | | | | | | | | | |
| | Nodes | 362 | 363 | 289 | 185 | 187 | 188 | 160 | 161 | 440 | 364 | 284 | 285 | 282 | 283 | 331 | 221 |
| **Route 5** | Arrival time | 28.83 | 29.63 | 33.45 | 36.53 | 39.93 | 42.85 | 44.42 | 46.77 | 49.37 | 52.44 | 57.92 | 57.92 | 59.04 | 62.94 | 69.16 | 75.88 |
| | Vehicle load | 15 | 24 | 36 | 50 | 60 | 73 | 85 | 97 | 109 | 120 | 130 | 146 | 161 | 168 | 178 | 192 |
| | Nodes | 380 | 383 | 88 | 382 | 385 | 384 | 307 | 93 | 310 | 309 | 20 | 21 | 25 | 17 | 26 | |
| **Route 6** | Arrival time | 12.75 | 17.27 | 20.67 | 23.3 | 30.97 | 33.95 | 37.63 | 43.48 | 49.01 | 50.78 | 59.86 | 61.53 | 63.16 | 67.61 | 77.96 | |
| | Vehicle load | 11 | 23 | 35 | 47 | 58 | 70 | 82 | 94 | 108 | 118 | 131 | 144 | 156 | 168 | 177 | |
| | Nodes | 111 | 109 | 127 | 126 | 129 | 123 | 122 | 121 | 120 | 446 | 130 | 110 | 392 | 102 | 103 | 393 |
| **Route 7** | Arrival time | 27.78 | 30.73 | 35.58 | 37.4 | 37.4 | 37.6 | 38.53 | 39.23 | 41.01 | 41.99 | 44.99 | 50.49 | 56.62 | 61.8 | 64.65 | 72.28 |
| | Vehicle load | 10 | 22 | 36 | 47 | 60 | 73 | 86 | 94 | 104 | 116 | 126 | 140 | 150 | 163 | 171 | 184 |
| | Nodes | 292 | 230 | 423 | 305 | 303 | 302 | 301 | 304 | 299 | 294 | 295 | 421 | 426 | 448 | | |
| **Route 8** | Arrival time | 27.12 | 28.35 | 31.68 | 36.13 | 38.95 | 42.5 | 45.42 | 49.45 | 54.03 | 55.76 | 59.26 | 65.28 | 71.7 | 77.17 | | |
| | Vehicle load | 12 | 25 | 36 | 49 | 62 | 69 | 84 | 99 | 109 | 122 | 135 | 150 | 160 | 169 | | |
| | Nodes | 447 | 166 | 288 | 194 | 70 | 145 | 136 | 133 | 134 | 135 | 286 | 287 | 170 | 290 | 365 | |
| **Route 9** | Arrival time | 29.22 | 30.12 | 33.17 | 36.19 | 43.54 | 45.62 | 49.72 | 51.84 | 51.84 | 51.84 | 56.92 | 58.25 | 62.35 | 72.63 | 77.46 | |
| | Vehicle load | 11 | 22 | 35 | 47 | 58 | 70 | 77 | 89 | 99 | 112 | 124 | 134 | 144 | 158 | 168 | |
| | Nodes | 329 | 325 | 323 | 326 | 330 | 327 | 322 | 321 | 332 | 324 | 328 | 401 | 404 | 405 | | |
| **Route 10** | Arrival time | 15.85 | 18.2 | 22.38 | 26.28 | 28.81 | 31.76 | 33.19 | 36.11 | 39.61 | 44.83 | 46.21 | 64.63 | 64.63 | 70.56 | | |
| | Vehicle load | 12 | 26 | 34 | 46 | 61 | 75 | 89 | 102 | 113 | 125 | 137 | 152 | 164 | 177 | | |
| | Nodes | 370 | 375 | 372 | 371 | 90 | 377 | 378 | 379 | 87 | 28 | 14 | | | | | |
| **Route 11** | Arrival time | 12.7 | 15.28 | 20.88 | 24.36 | 30.49 | 31.26 | 36.69 | 40.57 | 44.3 | 53.5 | 70.48 | | | | | |
| | Vehicle load | 8 | 19 | 31 | 41 | 56 | 68 | 79 | 95 | 106 | 118 | 133 | | | | | |
| | Nodes | 264 | 254 | 256 | 6 | 255 | 444 | 250 | 251 | 257 | 31 | 32 | 62 | 61 | 72 | 74 | 40 |
| **Route 12** | Arrival time | 10.9 | 18.53 | 21.21 | 26.63 | 30.18 | 38.18 | 40.1 | 41.38 | 42.5 | 53.37 | 53.7 | 55.63 | 59.25 | 62.88 | 68.6 | 84.42 |
| | Vehicle load | 11 | 24 | 36 | 49 | 62 | 75 | 88 | 101 | 111 | 123 | 135 | 145 | 156 | 168 | 179 | 193 |
| | Nodes | 117 | 163 | 34 | 171 | 137 | 140 | 141 | 138 | 191 | | | | | | | |
| **Route 13** | Arrival time | 29.43 | 34.93 | 42.38 | 45.16 | 45.79 | 49.47 | 50.7 | 55.93 | 62.45 | | | | | | | |
| | Vehicle load | 10 | 21 | 36 | 49 | 59 | 75 | 81 | 93 | 103 | | | | | | | |
| | Nodes | 46 | 89 | 243 | 247 | 186 | | | | | | | | | | | |
| **Route 14** | Arrival time | 27.27 | 44.25 | 59.73 | 64.45 | 70.28 | | | | | | | | | | | |
| | Vehicle load | 13 | 25 | 34 | 46 | 58 | | | | | | | | | | | |
| | Nodes | 300 | 274 | 436 | 424 | 293 | 296 | 297 | 275 | 276 | 439 | 430 | 428 | 427 | 65 | 66 | 96 |
| **Route 15** | Arrival time | 26.2 | 28.48 | 28.48 | 31.36 | 33.08 | 38.06 | 42.09 | 44.01 | 49.29 | 52.99 | 53.96 | 57.19 | 60.84 | 66.07 | 67.45 | 86.97 |
| | Vehicle load | 13 | 24 | 32 | 45 | 58 | 71 | 83 | 97 | 110 | 120 | 132 | 143 | 155 | 166 | 177 | 191 |
| | Nodes | 420 | 355 | 60 | 58 | 139 | 354 | 59 | 36 | 35 | 232 | 29 | 63 | 429 | 234 | 425 | 412 |
| **Route 16** | Arrival time | 12.88 | 18.03 | 23.83 | 24.36 | 24.36 | 25.31 | 26.26 | 27.81 | 30.56 | 36.94 | 38.96 | 44.38 | 45.68 | 47.16 | 51.96 | 55.36 |
| | Vehicle load | 10 | 21 | 31 | 44 | 60 | 73 | 81 | 90 | 103 | 117 | 127 | 139 | 154 | 168 | 180 | 195 |
| | Nodes | 313 | 315 | 311 | 317 | 316 | 91 | 92 | 450 | | | | | | | | |
| **Route 17** | Arrival time | 9.03 | 13.5 | 20.58 | 23.06 | 26.08 | 29.91 | 37.04 | 60.41 | | | | | | | | |
| | Vehicle load | 14 | 27 | 40 | 54 | 66 | 78 | 90 | 104 | | | | | | | | |
| | Nodes | 142 | 165 | 128 | 158 | 148 | 125 | | | | | | | | | | |
| **Route 18** | Arrival time | 32.28 | 38.48 | 45.56 | 45.56 | 52.34 | 58.12 | | | | | | | | | | |
| | Vehicle load | 10 | 21 | 31 | 43 | 55 | 68 | | | | | | | | | | |
| | Nodes | 100 | 101 | 113 | 112 | 395 | 115 | 118 | 116 | 357 | 216 | 217 | 366 | 369 | | | |
| **Route 19** | Arrival time | 23.77 | 30.3 | 32.68 | 35.55 | 42.03 | 50.58 | 51.88 | 54.43 | 57.45 | 61.37 | 61.37 | 64.19 | 69.56 | | | |
| | Vehicle load | 12 | 23 | 34 | 43 | 57 | 70 | 81 | 93 | 104 | 119 | 131 | 143 | 159 | | | |
| | Nodes | 224 | 229 | 409 | 422 | 149 | 146 | 147 | 298 | 431 | 278 | | | | | | |
| **Route 20** | Arrival time | 19.28 | 20.21 | 24.59 | 27.56 | 38.23 | 41 | 44.1 | 55.88 | 64.96 | 68.99 | | | | | | |
| | Vehicle load | 14 | 27 | 39 | 53 | 66 | 77 | 91 | 103 | 113 | 126 | | | | | | |
| | Nodes | 341 | 340 | 342 | 339 | 195 | 57 | | | | | | | | | | |
| **Route 21** | Arrival time | 32.27 | 37.09 | 44.22 | 52.7 | 62.67 | 72.54 | | | | | | | | | | |
| | Vehicle load | 14 | 26 | 33 | 45 | 58 | 73 | | | | | | | | | | |
| | Nodes | 42 | 43 | 416 | 414 | 417 | 415 | 41 | 37 | 38 | 196 | 438 | | | | | |
| **Route 22** | Arrival time | 19 | 22.18 | 30.65 | 34 | 37.57 | 43.55 | 49.95 | 56.05 | 56.67 | 64.22 | 72.64 | | | | | |
| | Vehicle load | 15 | 24 | 34 | 47 | 64 | 77 | 91 | 104 | 116 | 132 | 145 | | | | | |
| | Nodes | 73 | 79 | 277 | 68 | 67 | 69 | 83 | 84 | 291 | 71 | 235 | 227 | 231 | 353 | | |
| **Route 23** | Arrival time | 18.53 | 18.88 | 22.26 | 31.13 | 35.43 | 36.03 | 38.33 | 39.3 | 42 | 44.22 | 49.3 | 52.25 | 58.73 | 71.15 | | |
| | Vehicle load | 13 | 26 | 39 | 52 | 63 | 73 | 84 | 94 | 107 | 120 | 131 | 142 | 151 | 162 | | |
| | Nodes | 178 | 175 | 176 | 182 | 180 | 181 | | | | | | | | | | |
| **Route 24** | Arrival time | 33.22 | 38.9 | 38.9 | 54.65 | 58.42 | 60.52 | | | | | | | | | | |
| | Vehicle load | 14 | 27 | 39 | 52 | 62 | 76 | | | | | | | | | | |
| | Nodes | 82 | 433 | 434 | 80 | 81 | 164 | 281 | 177 | | | | | | | | |
| **Route 25** | Arrival time | 18.53 | 24.28 | 28.26 | 32.31 | 34.11 | 45.66 | 51.53 | 57.35 | | | | | | | | |
| | Vehicle load | 12 | 26 | 39 | 51 | 60 | 70 | 84 | 94 | | | | | | | | |

Table 40. Routing detail of Instance 8’. Part 1.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes | 82 | 433 | 434 | 80 | 81 | 164 | 281 | 177 | | | | | | | | |
| **Route 25** | Arrival time | 18.53 | 24.28 | 28.26 | 32.31 | 34.11 | 45.66 | 51.53 | 57.35 | | | | | | | | |
| | Vehicle load | 12 | 26 | 39 | 51 | 60 | 70 | 84 | 94 | | | | | | | | |
| | Nodes | 207 | 206 | 204 | 202 | 199 | 205 | 203 | 198 | 197 | 209 | 1 | | | | | |
| **Route 26** | Arrival time | 26.88 | 28.68 | 31.76 | 32.18 | 33.7 | 37.3 | 44.4 | 48.9 | 51.38 | 61.5 | 78.22 | | | | | |
| | Vehicle load | 14 | 25 | 34 | 46 | 55 | 66 | 76 | 87 | 99 | 112 | 121 | | | | | |
| | Nodes | 225 | 344 | 343 | 49 | 233 | 54 | 53 | 52 | | | | | | | | |
| **Route 27** | Arrival time | 18.4 | 27.2 | 29.5 | 36.58 | 43.13 | 53.93 | 61.91 | 66.91 | | | | | | | | |
| | Vehicle load | 8 | 21 | 35 | 47 | 56 | 69 | 82 | 96 | | | | | | | | |
| | Nodes | 236 | 248 | 367 | 249 | 222 | 218 | 220 | 219 | 240 | | | | | | | |
| **Route 28** | Arrival time | 22.2 | 26.18 | 28.9 | 29.2 | 38.7 | 42.47 | 42.47 | 49.45 | 59.53 | | | | | | | |
| | Vehicle load | 10 | 22 | 35 | 45 | 57 | 69 | 82 | 95 | 110 | | | | | | | |
| | Nodes | 403 | 179 | 399 | 400 | 398 | 402 | 184 | | | | | | | | | |
| **Route 29** | Arrival time | 21.68 | 35.96 | 43.63 | 43.63 | 45.06 | 45.06 | 58.33 | | | | | | | | | |
| | Vehicle load | 12 | 24 | 36 | 49 | 63 | 76 | 87 | | | | | | | | | |
| | Nodes | 335 | 338 | | | | | | | | | | | | | | |
| **Route 30** | Arrival time | 37.32 | 52.7 | | | | | | | | | | | | | | |
| | Vehicle load | 10 | 22 | | | | | | | | | | | | | | |
| | Nodes | 312 | 319 | 183 | 172 | | | | | | | | | | | | |
| **Route 31** | Arrival time | 7.23 | 19.58 | 41.21 | 55.91 | | | | | | | | | | | | |
| | Vehicle load | 14 | 27 | 40 | 49 | | | | | | | | | | | | |
| | Nodes | 449 | 24 | 23 | 22 | 27 | 19 | 18 | | | | | | | | | |
| **Route 32** | Arrival time | 8.92 | 28.32 | 30.55 | 34.07 | 45.87 | 56.05 | 63.23 | | | | | | | | | |
| | Vehicle load | 12 | 23 | 34 | 48 | 56 | 72 | 85 | | | | | | | | | |
| | Nodes | 11 | 262 | 356 | 260 | 445 | 418 | 75 | 76 | 77 | 78 | 273 | 272 | 435 | 432 | 269 | 267 |
| **Route 33** | Arrival time | 7.42 | 13.7 | 17.02 | 20.74 | 24.02 | 31.97 | 37.62 | 39.4 | 41.45 | 44.87 | 47.45 | 48.63 | 54.11 | 57.44 | 64.37 | 72.12 |
| | Vehicle load | 9 | 20 | 30 | 41 | 53 | 64 | 79 | 89 | 100 | 113 | 129 | 143 | 155 | 164 | 176 | 187 |
| | Nodes | 271 | 270 | 268 | 104 | 242 | 359 | | | | | | | | | | |
| **Route 34** | Arrival time | 12.43 | 19.01 | 24.39 | 47.36 | 60.88 | 66.21 | | | | | | | | | | |
| | Vehicle load | 14 | 26 | 40 | 50 | 64 | 78 | | | | | | | | | | |
| | Nodes | 39 | 413 | 12 | 48 | 45 | 47 | 411 | | | | | | | | | |
| **Route 35** | Arrival time | 17.53 | 29.68 | 39.71 | 46.24 | 49.67 | 51.44 | 61.52 | | | | | | | | | |
| | Vehicle load | 8 | 16 | 26 | 38 | 52 | 66 | 79 | | | | | | | | | |
| | Nodes | 396 | 397 | 241 | 245 | 360 | | | | | | | | | | | |
| **Route 36** | Arrival time | 26.28 | 39.56 | 54.88 | 60.38 | 63.13 | | | | | | | | | | | |
| | Vehicle load | 16 | 29 | 42 | 54 | 69 | | | | | | | | | | | |
| | Nodes | 238 | 214 | 361 | 239 | 212 | 213 | | | | | | | | | | |
| **Route 37** | Arrival time | 30.83 | 40.26 | 48.84 | 50.86 | 58.36 | 61.53 | | | | | | | | | | |
| | Vehicle load | 12 | 25 | 33 | 42 | 56 | 67 | | | | | | | | | | |
| | Nodes | 2 | 5 | 3 | 4 | 263 | 261 | 253 | 9 | 8 | 7 | 211 | | | | | |
| **Route 38** | Arrival time | 24.87 | 26.84 | 29.17 | 32.04 | 36.11 | 40.91 | 46.14 | 52.82 | 54.5 | 56.57 | 67.37 | | | | | |
| | Vehicle load | 13 | 23 | 33 | 42 | 55 | 67 | 80 | 95 | 107 | 121 | 135 | | | | | |
| | Nodes | 10 | 210 | 347 | 345 | 346 | 56 | | | | | | | | | | |
| **Route 39** | Arrival time | 14.63 | 27.35 | 40.87 | 50.9 | 55.1 | 61.63 | | | | | | | | | | |
| | Vehicle load | 16 | 31 | 42 | 57 | 71 | 84 | | | | | | | | | | |
| | Nodes | 13 | 55 | 51 | 50 | | | | | | | | | | | | |
| **Route 40** | Arrival time | 29.67 | 48.2 | 53.25 | 57.85 | | | | | | | | | | | | |
| | Vehicle load | 12 | 24 | 35 | 48 | | | | | | | | | | | | |
| | Nodes | 15 | 16 | 394 | 114 | 97 | | | | | | | | | | | |
| **Route 41** | Arrival time | 14.02 | 16.94 | 31.92 | 48.42 | 70.29 | | | | | | | | | | | |
| | Vehicle load | 11 | 22 | 30 | 41 | 55 | | | | | | | | | | | |
| | Nodes | 30 | 228 | 44 | 410 | 226 | 358 | 443 | | | | | | | | | |
| **Route 42** | Arrival time | 20.08 | 25.7 | 35.83 | 42.35 | 48.38 | 55.18 | 59.88 | | | | | | | | | |
| | Vehicle load | 11 | 22 | 38 | 51 | 63 | 75 | 87 | | | | | | | | | |
| | Nodes | 124 | 237 | 442 | 215 | 246 | 349 | | | | | | | | | | |
| **Route 43** | Arrival time | 26.78 | 44.88 | 46.76 | 48.34 | 53.61 | 71.73 | | | | | | | | | | |
| | Vehicle load | 10 | 20 | 27 | 38 | 49 | 62 | | | | | | | | | | |
| | Nodes | 320 | 318 | 280 | 306 | 279 | 314 | 374 | 373 | 98 | 99 | 381 | 376 | | | | |
| **Route 44** | Arrival time | 9.66 | 17.51 | 18.86 | 22.94 | 25.89 | 33.19 | 45.11 | 45.89 | 51.87 | 53.72 | 59.17 | 66.3 | | | | |
| | Vehicle load | 11 | 22 | 37 | 47 | 62 | 74 | 84 | 96 | 111 | 123 | 135 | 146 | | | | |
| | Nodes | 244 | 223 | 441 | 368 | 419 | 437 | | | | | | | | | | |
| **Route 45** | Arrival time | 25 | 32.68 | 41.11 | 44.13 | 57.96 | 62.03 | | | | | | | | | | |
| | Vehicle load | 15 | 23 | 35 | 45 | 60 | 70 | | | | | | | | | | |
| | Nodes | 64 | | | | | | | | | | | | | | | |
| **Route 46** | Arrival time | 33.07 | | | | | | | | | | | | | | | |
| | Vehicle load | 18 | | | | | | | | | | | | | | | |
| | Nodes | 94 | 95 | 265 | 351 | 352 | 252 | 259 | 258 | 350 | 406 | | | | | | |
| **Route 47** | Arrival time | 16.01 | 20.54 | 24.26 | 38.18 | 40.81 | 50.86 | 53.84 | 56.99 | 61.99 | 68.31 | | | | | | |
| | Vehicle load | 14 | 26 | 38 | 48 | 60 | 73 | 87 | 101 | 113 | 125 | | | | | | |
| | Nodes | 266 | 408 | 407 | 348 | 333 | | | | | | | | | | | |
| **Route 48** | Arrival time | 18.76 | 29.33 | 34.23 | 38.66 | 47.74 | | | | | | | | | | | |
| | Vehicle load | 9 | 22 | 39 | 50 | 65 | | | | | | | | | | | |
| | Nodes | 173 | | | | | | | | | | | | | | | |
| **Route 49** | Arrival time | 24.18 | | | | | | | | | | | | | | | |
| | Vehicle load | 10 | | | | | | | | | | | | | | | |
| | Nodes | 174 | | | | | | | | | | | | | | | |
| **Route 50** | Arrival time | 34.84 | | | | | | | | | | | | | | | |
| | Vehicle load | 11 | | | | | | | | | | | | | | | |

Table 41. Routing detail of Instance 8’. Part 2.